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**THE HISTORY OF THE
AIRCRAFT STRUCTURAL INTEGRITY PROGRAM**

JUNE 1980

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**AEROSPACE STRUCTURES
INFORMATION AND ANALYSIS CENTER**

**OPERATED FOR THE FLIGHT DYNAMICS LABORATORY
BY ANAMET LABORATORIES, INC.**

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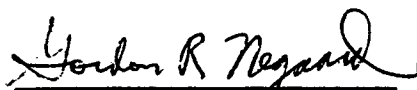
FOREWORD

An oft-quoted phrase states, "Those who forget the lessons of history are doomed to repeat them." This report attempts to trace the history of the Aircraft Structural Integrity Program to its earliest beginnings. Documented concern for structural integrity dates back to the days of the Wright Brothers. In terms of its modern meaning, however, the Aircraft Structural Integrity Program (ASIP), really began in the 1950's with the need to guard against fatigue failure. In this context, ASIP was developed not only as an instrument to prevent costly structural failures in modern, high performance aircraft, but also to serve as a corporate memory to insure that the lessons of history such as the B-47 crisis are not repeated.

This report summarizes the development of the Aircraft Structural Integrity Program. The history of the program is traced back to the earliest concerns for structural integrity and followed through its development until ASIP became a permanent USAF requirement when Air Force Regulation 80-13 established detailed requirements for all manned USAF aircraft.

The report was prepared by the Aerospace Structures Information and Analysis Center, which is operated for the Flight Dynamics Laboratory by Anamet Laboratories, under Contract No. F33615-77-C-3046.

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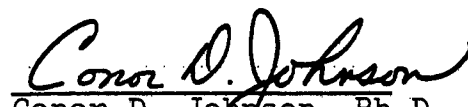

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SECTION I

INTRODUCTION

A series of catastrophic B-47 accidents in early 1958 focused USAF attention on structural fatigue problems of high-performance aircraft, involving not just the B-47 but all USAF aircraft whose useful service life was of critical interest to the nation's security position at the time. This official concern precipitated an extensive structural integrity investigation of all high performance manned aircraft, current and future. The inquiry encompassed three main areas: (1) emergency measures to rehabilitate the B-47, (2) basic and applied research to make structural fatigue predictable by establishing its causes, and (3) a long range program to combine this information with the results of aircraft tests to arrive at improved data for design criteria and a more accurate prediction of aircraft life [1].* This program, as it unfolded, was "not a routine investigation which a few individuals could resolve in a few weeks or months of concentrated engineering, but one which promises to persist as long as the Air Force continues to design and build high performance manned aircraft."

The above statement, made in 1959 when the program was just beginning, was remarkably prophetic. The Aircraft Structural Integrity Program, or "ASIP" as it came to be known, was soon to become a permanent part of Air Force engineering technology. Born of necessity out of the B-47 structural crisis in 1958, ASIP underwent continued revision during a maturation period of more than ten years as the Air Force and the aircraft industry jointly sought for improvements in design philosophy and technology to meet the ASIP objectives. During this period the program provided the incentive for the development of new concepts such as damage tolerance, durability, and fracture mechanics, in addition to stimulating research in the areas of design, stress analysis, loads and environment, inspection techniques, and testing. ASIP can be said to have come

*Numbers in brackets denote References.

of age during the 1968-1971 era, the period of the next major airframe crisis involving the F-111 airframe. The F-111 recovery program required the application of almost every bit of technology available to the aircraft engineer, demonstrating anew the necessity of a program to uncover deficiencies early in the design and procurement cycle of new aircraft. The alternative is an expensive retrofit program after the introduction of the aircraft. By this time, ASIP concepts had gained sufficient acceptance and respectability within the aerospace community that it became a permanent USAF requirement with the publication of Air Force Regulation 80-13 establishing detailed ASIP requirements for all manned USAF aircraft [2].

The year 1980 appears an opportune time to examine the results of the implementation of these requirements and to document the history of ASIP from its inception to the present. The purpose of this report is not so much to discuss the technical aspects and merit of the program as it is to trace the development of the philosophy and technology involved. This study will try to place the development of ASIP into historical perspective against the political and economic requirements of the times in the belief that a knowledge of the history of structural integrity will improve the understanding of the objectives and goals of the Aircraft Structural Integrity Program.

SECTION II

THE ORIGINS OF STRUCTURAL INTEGRITY

The earliest use of the term "structural integrity" in conjunction with aircraft structural design is difficult to ascertain. The term appears to have been in general use by the 1950's since Military Specifications published in 1954 refer to "the demonstration of the structural integrity of airplanes by static structural test procedures," [3], and to "a structural integrity flight demonstration" [4]. Although the exact meaning of "structural integrity" is not further defined in these specifications, a definition of the term can be found in the United States Air Force Dictionary published in 1956. This dictionary states that structural integrity is "the property of an airframe to withstand the loads for which it is designed" [5].

For years the method for ensuring structural integrity was almost as simple and straightforward as this definition. In fact, the method in use in 1954 was almost identical to that used by Wilbur and Orville Wright in 1903. Professor Nicholas Hoff states in a paper published in 1955 that the Wright Brothers had "confidence in the structural integrity of their machines" [6]. He goes on to document the fact that "the Wright Brothers performed a stress analysis of their first power machine and conducted static tests far in excess of the load that is required of it in flight." The systematic engineering approach used by the Wright Brothers was so effective that for more than 50 years it was the primary method of providing safety in aircraft design [7]. In essence, the method consisted of a factor of safety applied to the expected loads, supported by component testing and demonstrated by a full scale static test.

Professor Hoff sums up in his paper: "These excerpts from the Wright papers indicate that the brothers had no doubts about their ability to design a structure safely when the loads were known. They did not worry much even about the load; a

safety factor applied to forces maintaining static equilibrium with the weight seemed to them a satisfactory solution of the problem." According to several authors, the factor of safety was a design factor used to take care of five sources of variability that could not be properly assessed by the technological means available at the time [7,8]. These five sources are most simply stated as:

- (1) Uncertainties in loads.
- (2) Inaccuracies in structural analysis.
- (3) Variations in strength properties of materials.
- (4) Deterioration during service life.
- (5) Variations in construction quality between identical components (build standards).

This concept of a factor of safety provided an almost universally acceptable measure of flight safety until the mid-1950's [9]. This does not imply that there were no structural problems during this period. It implies instead that the factor of safety provided an acceptable balance between the need for an efficient, lightweight airframe and the continuing demand for bigger, faster and higher altitude aircraft. Design weaknesses or faulty design practices disclosed during static testing were corrected by modification or redesign as necessary. If additional design or operational problems arose or occurred during flight, corrective changes were made to the design specifications, load prediction techniques, manufacturing techniques, environmental standards, or operational restrictions of the airplane. Thus, the entire design and test process was a procedure that, by creating a large data base, helped narrow some of the uncertainties in the five sources of variability, particularly load prediction, structural analysis, and build standard. The other two sources of variability, material properties and deterioration in service, showed little or no improvement [8]. However,

the net result still helped create safer and more efficient aircraft as evidenced by accident statistics of the period [10]. On the other hand, the continuing drive for higher performance aircraft with the resulting need for newer, less well-defined materials to achieve this performance, continued to eat into the margin for error provided by the factor of safety. On the whole, though, a rather satisfactory situation existed, one that the structural engineer felt comfortable with. Progress was slow and steady and the guidelines were simple.

This rosy world began to fall apart after World War II as fatigue problems began to surface--in civilian airlines at first, but eventually in USAF aircraft as well. There were some reflections and temporary concern by the Air Force for fatigue problems with the crashes of the Martin 202 in 1948 and the British DeHavilland Comet in 1954, as well as some indications of fatigue with military aircraft [11]. During World War II, airplanes did not accumulate too many flight hours a year, and only the training airplanes were flown enough hours to warrant fatigue investigation. The first military aircraft used for a fatigue test was a North American AT-6 advanced trainer. This test, done in 1945 at Wright Field, Ohio, was crude but adequate. Repeated testing of the wings to limit load was done until failure occurred. The inspection methods were also crude, mostly aural or visual in order to detect or find a crack. In 1948, fatigue tests were conducted on F-84D wings. This testing was continued in 1952 on F-84G wings from airplanes used in the Korean conflict. Again the normal method, cycling to limit load until failure occurred, was used [12].

The first indication of a fatigue problem in service came from an inspection after a left wing failure and crash of an F-89C at an air show in 1952. Other serious structural fatigue incidents followed in rapid succession; the B-36 in 1952, the F-84 in 1953, the F-86 in 1955, and the F-101 in 1958 are typical examples. Quick action in the form of expedited investigation

and retrofit programs usually sufficed to correct the situation in each type of aircraft. Then, just as it began to appear that the situation was under control and that a degree of compatibility had been reached between aircraft structural dependability and metal fatigue, the problem was again brought into sharp focus. This time the critical factor was a series of catastrophic fatigue failures in the B-47 fleet early in 1958 [13].

SECTION III

THE B-47 CRISIS

During the "cold war" of the 1950's, the national security of the United States hinged on the John Foster Dulles doctrine of "massive nuclear retaliation." The principal American deterrent force was the United States Air Force Strategic Air Command with its turbojet fleet of B-47 and B-52 bombers. Americans in the late 1950's were almost complacent about the mantle of protection which this bomber fleet afforded. This complacency was shaken in the fall of 1957 with the announcement of "SPUTNIK," reflecting a startling Russian technical achievement and requiring a revision of how soon the Russians might be able to counter the Strategic Air Command. Despite the fact that the Communists adopted a more aggressive international attitude, the American retaliatory force still seemed an effective balancing force in deterring Communist ambitions. The complacency was completely shattered in the spring of 1958 when a crisis temporarily immobilized the entire B-47 fleet, threatening to drop the B-47 from the active inventory several years before the Air Force had counted on replacing it [14]. Under a heavy cloak of secrecy, the Air Force and the aviation industry rallied to save the B-47 from the scrap pile. A tremendous engineering effort, identified as project MILK BOTTLE, rehabilitated the ailing bomber and gave it new life [15].

The importance of the B-47 to those concerned with the defense and security of the United States in the 1950's may be difficult to understand today, but at the time, the B-47 was the numerical backbone of the Strategic Air Command. The first swept-wing jet bomber to be built in quantity, 2,041 were produced by three different manufacturers (Boeing, Douglas, and Lockheed) by the time the last B-47 rolled off the assembly line in February 1957. The Air Force had counted on using the B-47 as its medium-range strategic bomber for at least another seven years after 1958. This fact alone would have justified

the apprehension which swept the defense establishment when this key aircraft threatened to become unusable years before its anticipated obsolescence date. The B-47 crisis, serious in itself, raised other questions which troubled American planners. Just how dangerous and far-reaching was the lack of theoretical and actual knowledge concerning structural fatigue? What did the B-47's demonstrated weakness imply for other current and planned high-performance manned aircraft, such as the eight-jet B-52, the supersonic B-58, the KC-135 jet tanker, and the futuristic B-70 and F-108?

To understand the relevance of the B-47 problem to potential problems with other aircraft in the USAF fleet, it is helpful to consider the history of the B-47, and the similarities and the uniqueness of the B-47 as compared to other military aircraft. Built as an experimental multi-engine jet bomber in competition with the XB-46 and XB-48, the XB-47 was flying before bonafide military characteristics were established by headquarters, USAF. Its radically new design, incorporating six jet engines slung on pylons beneath an extremely thin and flexible laminar-flow swept-back wing, helped the aircraft achieve a performance considerably better than its designers had hoped [16]. A top speed in excess of 600 mph allowed it to outfly almost every fighter in existence at the time. Because of this outstanding performance, the B-47 was selected by SAC as its new high altitude medium bomber in 1950.

The prototype B-47 had made its first flight on December 17, 1947, with a gross weight of 125,000 pounds, powered by six 4,000 pound thrust jet engines. The gross weight grew to 185,000 pounds for the B-47B and reached 206,700 pounds for the B-47E as a result of structural strengthening, equipment changes, and the addition of extra fuel capacity to increase the range. To maintain the desired performance, the engine thrust was increased to 5,200 pounds on the B-47A, 5,800 pounds on the B-47B, and finally 6,000 pounds on the B-47E. The structural design

of the B-47 series aircraft was accepted by the Air Force based on a static test of the B-47B in 1950 and a flight load survey demonstration of a B-47B from September 1952 to March 1954. No finite service life was specified for the B-47 series aircraft, so the number of flying hours to be expected during the life of one of the airplanes did not enter into the acceptance procedure. It was procured, however, with the intent that it would not be replaced until 1965. In actual fact, most of the operational B-47 fleet was phased out by 1966, although a few aircraft remained in service as late as 1969. The B-47 thus had a relatively long career, although its future looked dim in 1958.

The structural analysis of the B-47, including the standard static test and the abbreviated flight load survey, proved that the item under test would support at least 150 per cent of its design limit load. However, it provided no assurance that the test item would survive smaller cyclic loads in the order in which actual flight imposed them. Thus, repeated cycles of less than maximum loads, including warping, twisting and bending motions, might do more damage than the direct application of much larger loads. Absence of precise information concerning these inflight loads, theoretical or actual, explained how an unexpected fatigue problem could suddenly threaten the life of the B-47 aircraft. Fatigue analysis was not a sufficiently exact science to permit accurate prediction and warning, but it was clear to laboratory scientists that several factors in the use of the B-47 would shorten its expected life. Unfortunately, they could not identify 500, 1500, or 2000 flight hours as the danger point; nor, except in a general way, could they pinpoint the aircraft members which were receiving the most severe stress from additional loads [1]. They could only argue that B-47's performing low altitude missions and those with high flight times be carefully inspected for external signs of stress.

Problems with the B-47 could be anticipated from several key factors. The growth in gross weight aggravated the already severe problem of the reduced structural weight to gross weight ratios of modern aircraft design. The increase in engine thrust, due to larger engines and a water-injection modification which provided a 17 per cent increase in takeoff power, intensified the strains on the fuselage and wings. Rockets used for takeoff assistance permitted shorter takeoffs. However, they also gave the aircraft structure a solid "boot" from an unexpected direction [1]. Less tangible questions were being raised about the effects on the aircraft structure of acoustic noise and heat emanations from the jet exhaust, since these fatigue effects were just beginning to be recognized and investigated. More important factors were the changes in service usage of the aircraft.

Designed to be a high-altitude bomber, the B-47 was used largely in that manner for the first ten years of its existence. However, during the last half of 1957, with Air Proving Ground approval, SAC began employing the bomber extensively at low altitudes [15]. These low-level missions included a structure-wrenching low-altitude bombing system maneuver (LABS) for low-level delivery of nuclear weapons, and a strenuous "pop-up" bombing run. This operation also caused additional stresses due to the atmospheric turbulence encountered below 1,000 feet. In addition, the increased range due to strategic commitments required more frequent refueling missions, each of which created unusual strains in the airframe due to the maneuver loads required to stay within the allowable bomber-to-tanker relative positioning limits during refueling. Repeated takeoffs and landings in training exercises also added extra, unplanned stresses due to the dynamic aspects of landing, taxi, runway roughness effects, and braking conditions. The additional structural loads imposed by all of these effects were difficult

to measure. In any case, so long as the B-47 performed its varied missions satisfactorily, it was hard to justify the funds expenditure that a serious investigation of structural loads would require.

Conclusive evidence that a structural crisis had been reached came on 13 March 1958 when two B-47's broke up in midair in separate incidents. Near Homestead Air Force Base, Florida, a B-47B disintegrated at 15,000 feet, three minutes after takeoff. Its center wing section failed approximately at buttock line 45. (Figure 1 illustrates some of the critical locations on the B-47.) The aircraft had a total flight time of 2,077 hours and thirty minutes at the time of the accident. The same day a TB-47B broke up at 23,000 feet over Tulsa, Oklahoma, after the bottom skin plate of the left wing failed at buttock line 35, causing the left wing to break off at the same point. This plane had flown a total of 2,418 hours and 45 minutes. While Air Force and contractor agencies were investigating these two accidents, three more occurred, indicating that the crashes of 13 March were not isolated events.

These successive accidents further served notice that the flaws might show up in almost any B-47, not just those with over 2,000 flight hours. On 21 March, as a result of over-stress from a pull-up, a B-47E disintegrated in midair near Avon Park, Florida. This aircraft had a total flight time of only 1,129 hours and 30 minutes. Next, a B-47E seemed to explode at 13,100 feet just prior to a refueling rendezvous near Langford, New York, on 10 April. This aircraft had a flight time of 1,265 hours and 30 minutes. The final tragedy in this series occurred on 15 April when another B-47E, with a total flight time of 1,419 hours and 20 minutes, took off into a storm from McDill Air Force Base, Florida, and disintegrated shortly afterwards. The pilot was believed to have encountered gusts of 80 to 100 miles per hour. One

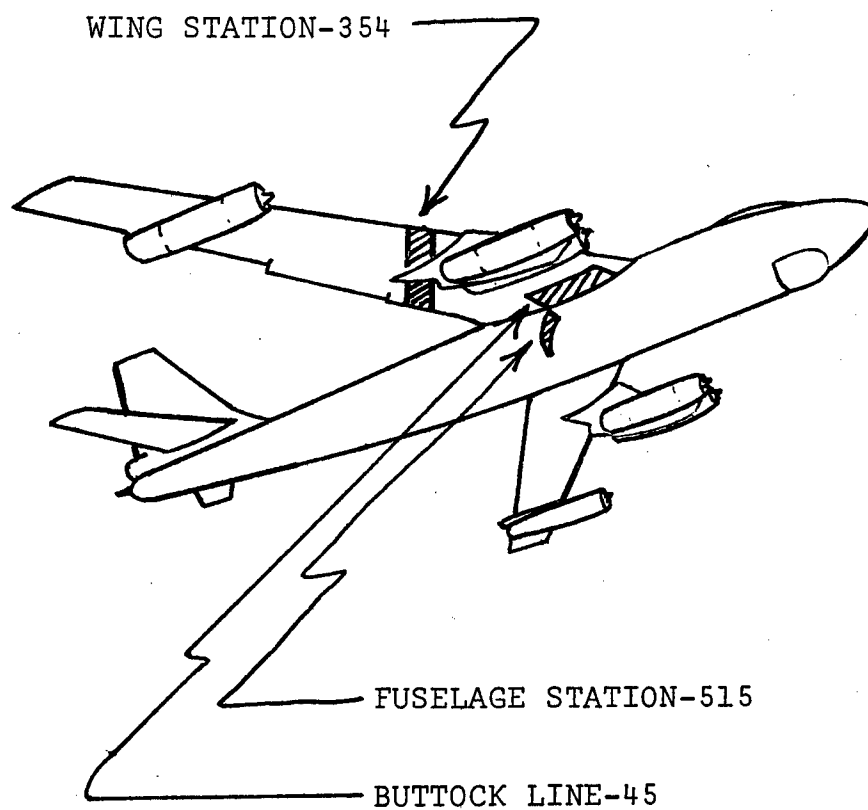


Figure 1. Some Fatigue Critical Locations on the B-47

of these accidents was ascribed to the pilot exceeding the aircraft structural limits in a pull-up, but the remaining four were clearly due to structural fatigue failure.

The parties most immediately concerned in the crisis were the Boeing Airplane Company, which manufactured the B-47, the Strategic Air Command (SAC), which was the principal user of the B-47, and the Air Material Command (AMC), which was responsible for this and other in-service aircraft. The magnitude of the threat posed by these fatigue failures also quickly involved the Air Research and Development Command (ARDC) and its Wright Air Development Center (WADC). WADC was intimately involved from the first, especially the structural experts of the Aircraft Laboratory and the metallurgical scientists of the Materials Laboratory. The National Advisory Committee for Aeronautics (NACA) also participated actively in the efforts to meet this emergency.

The immediate problem was to keep the B-47's flying, since national security considerations and an approaching summit meeting in Geneva forbade a lengthy grounding, much less a complete discard, of this substantial portion of the bomber fleet. Efforts to correct the structural problems by splicing, reinforcing or replacing the affected members was the first response to the crisis. Such stopgap structural corrections would at least permit SAC to continue using the aircraft, though with restrictions on speed, weight and in-flight maneuvers. A logical continuation of the emergency corrective program would verify the interim "fixes" and extend them to the point of guaranteeing an "adequate" service life for the B-47.

Several related actions comprised the special engineering effort to restore the B-47 to its former usefulness. Major General Thomas P. Gerrity, Commander of the Oklahoma City Air Material Area (OCAMA), identified his immediate concerns as

"inspection criteria, flight restrictions, additional instrumentation, and a further test program" [17]. An official inquiry into the two accidents of 13 March was already underway. By 23 March, restrictions on flight maneuvers were being urged by WADC. On 4 April ARDC agreed that "continued, unrestricted operation of the B-47 fleet was hazardous." By 11 April, specific limitations such as 360 knot indicated air speed and 1.5 g maneuvers were in effect. Formal restrictions were laid down on 25 April, applying to all B-47's except those previously inspected for cracks at all critical points. Low-level flying, except for takeoff and landing, was banned. Aircraft gross weight could not exceed 136,000 pounds (without external tanks) or 185,000 pounds (with full external tanks). Maneuvers were to extend no further than 1.5 g's on a 30 degree bank. Maximum indicated air speed was to be 310 knots, with continuing restrictions on stalls, buffet, flights through turbulence, and touch-and-go landings. Finally, there were additional rules concerning the conditions under which refueling could be accomplished.

Operating under these flight restrictions, SAC was able to continue to fly training and operational missions with a minimum of hazard until each aircraft could be inspected and retrofitted. The aircraft inspections were initially based on the investigations of the two aircraft which crashed on 13 March, 1958. This investigation led to Technical Order 1B-47-1016 published on 16 April, which incorporated inspection of buttock lines 35 and 45 (BL-35 and BL-45) with inspection of wing station 354 (WS-354). This was quickly rescinded on 22 April after investigation of the 10 April crash showed that accident to be caused by a failure at fuselage station 515 (FS-515). As a result, T.O. 1016 was replaced on 25 April by a requirement that all aircraft be inspected at all four of these critical points [1]. Other directives quickly followed (Technical Orders 1B-47-1020 and 1B-47-1022)

which contained temporary measures which would at least keep most of the B-47's flying. On aircraft without cracks, certain critical holes at WS-354 and BL-45 were reamed out and received oversized bolts. The aft wing-to-body fittings at FS-515 were also reamed out and received oversized pins. This pin, weighing approximately 25 pounds, was sized and shaped like a milk bottle, eventually resulting in the name "Project Milk Bottle" for the inspection and retrofit project.

The ultimate "fix" for the B-47 wing was incorporated in Technical Order 1B-47-1019, which appeared on 29 May 1958, along with the kits required to reinforce the wing root. The work called for in these three technical orders (1019, 1020, and 1022) comprised the phase of the B-47 rescue work identified as Project Milk Bottle. This endeavor eventually encompassed structural modification of 1,622 B-47 aircraft. The first half of May was a build-up period, the project crested in August and by 1 January 1959, all B-47's had been inspected and reworked at least once [15].

The \$62 million cost of Project Milk Bottle did not necessarily insure SAC that it now had no fatigue problems with the B-47. By the beginning of April 1958, the parties concerned were already in general agreement that only cyclic testing could provide valid proof that the B-47 fixes would guarantee an "adequate" service life for the aircraft. To formulate valid test cycles, however, it was first necessary to define the environment in which the aircraft would perform. This meant identifying the number of takeoffs, landings, accelerated climbs or letdowns, abrupt turns, low altitude missions and flights through turbulent weather conditions. Of necessity, the spectrum for cyclic testing had to be based on available data. At the same time, it was recognized that gaps existed in this information and programs were being undertaken to collect data to fill this need. In the meantime, cyclic tests of the B-47 would indicate whether the engineering

repairs had restored a useful service life to the aircraft. In addition, the tests would be a preliminary step in the larger structural integrity program which the B-47 crisis had spawned [1]. The engineers would be interested in when cracks first appeared during the cyclic test, where the cracks were located, and how fast they spread under continued applications of a spectrum of loading.

By mid-May, 1958, a canvass of available facilities and interested parties resulted in a decision to cyclic-test the B-47 to destruction at three independent establishments--the Boeing plant at Wichita, Kansas; the Douglas plant at Tulsa, Oklahoma; and the NACA laboratory at Langley, Virginia. Boeing began its testing early in July, Douglas began late in July, and NACA started almost a month later. However, neither the Boeing nor the Douglas aircraft had received the "1019 fix" so testing on both was stopped temporarily in order to install this modification. The Langley airplane had undergone this modification before its cycle test began.

When the tests began, the wing seemed the B-47's critical structural element, but one month of accelerated test activity uncovered a new fatigue danger point--the fuselage longeron at fuselage station 508. On 8 August, after the application of 1,275 equivalent flight hours, both upper fuselage longerons on the Boeing test aircraft failed during a 90 percent limit load test. The fuselage skin had shown warning cracks but the longeron collapse was still a surprise, especially since the aircraft had accumulated a total time (actual plus simulated flight) of only 3,442 hours [1]. The fuselage was replaced, retaining the original test wing, and the cyclic test was started over again on 8 September. On 16 September, with a total time for the replacement fuselage of 2,156 hours, a crack again appeared at fuselage station 508. On the same day a service B-47 with 2,900 hours of actual flight time was also discovered to have longeron cracks. Meanwhile, on

13 September, the same fate almost befell the test aircraft at Douglas. Crack detection wires, installed after the first Boeing test mishap, prevented a complete failure, but the Douglas disaster repeated Boeing's even to the location of the crack and the timing (the Douglas aircraft had a total time of 3,022 hours).

Consultation led to a decision to replace both upper fuselage longerons on both the Boeing and Douglas aircraft. In addition, the replacement longerons incorporated a reinforcement that Boeing had engineered after the August 8 failure. This was accomplished, and Boeing and Douglas resumed testing on 13 October 1958.

In early November, the Boeing test aircraft failed at buttock line 45 after a total of 5,872 actual and simulated hours on the wing. After repair, tests resumed on 4 December. In mid-December, a 27 inch crack appeared in the aircraft skin at right buttock line 32. The aircraft's total time was now 6,397 hours, of which 4,626 were simulated flight hours on the longeron modification. Boeing replaced the damaged skin panel and tested until 21 December, stopping with a total time on the test aircraft of 6,922 actual and simulated flight hours. The decision to discontinue the test short of actual destruction stemmed from two considerations; the longerons had successfully withstood 5,151 equivalent test hours, and the wing had been extensively spliced and patched so that it no longer resembled the actual B-47 configuration [1]. Therefore, no really useful information would derive from future tests. A teardown inspection followed so that test results could later be compared to other B-47 structural integrity findings.

The aircraft under test at Langley developed fuselage skin cracks at 4,243 total hours. After repairs, this B-47 held up until cracks appeared in the steel splice plates of the 1019 modification" at 5,468 hours and again at 5,818 hours.

A crack was also discovered in the splice plate at wing station 179 at that time. This was counted as a major failure, and the Langley test was ended. The total time on the longeron repair was 4,550 hours, but Langley personnel reported that their "bird" was tired and that it was starting to develop a rash of small cracks [1].

Thus, the Douglas B-47 was left to carry on the burden of destruction testing. Though fuselage skin cracks necessitated repairs, this airplane went on to pile up a total of 6,425 hours before three cracks were discovered in the web of a rib at wing station 258. These cracks were stop-drilled, a temporary measure to arrest the cracks and keep them from spreading. At 7,145 hours, cracks similar to those which had ended the test life of the Langley B-47 appeared on the Douglas Aircraft. Stop-drilling arrested these cracks, but the process had to be repeated twice more at 7,845 hours and at 8,195 hours. In each case, the cracks would have produced wing failure if they had gone undetected. By using these stopgap measures, the Douglas B-47 survived approximately 10,000 hours fatigue testing before the right lower wing lower skin panel failed and brought an end to the cyclic testing in February 1959. Significantly, the point of collapse was the wing skin closure panel at wing station 175, less than four inches from the point at which the Langley aircraft had finally come apart.

Insofar as possible, all three test aircraft received identical cyclic tests. Strategic Air Command mission profiles served as the basis for a composite series of simulated missions designed to duplicate the varying loads imposed on the B-47 in operational use. The stresses represented those on an aircraft with a takeoff gross weight of 170,000 pounds, flying missions averaging just over six hours. Firm decisions from the cyclic tests were not made immediately because investigators wanted to correlate these results with those from other

portions of the expanding structural integrity program. The three fatigue test aircraft had, to a considerable degree, proved the reliability of the 1019 wing modification and the longeron repairs. By November 1958, it seemed that a guarantee of 3,000 hours was certain, and that further evaluation of the test results might boost this figure to 5,000 hours. Further extension of the B-47's service life was questionable. Colonel R. D. Keator, Chief of the WADC Aircraft Laboratory, was not especially encouraging. In December, he agreed that it might be possible to guarantee the aircraft's useful life beyond 5,000 hours, but he indicated that such a gain could only be achieved by identifying new critical areas and engineering "fixes" for them. The result might not be worth the effort, Colonel Keator suggested, as it could conceivably degrade the aircraft's performance [18].

SECTION IV

THE BIRTH OF ASIP AS A PROGRAM

Insuring the continued usefulness of the B-47 was the most immediately urgent matter in 1958, but the Air Force clearly understood the warning implicit in the B-47 crisis. General Thomas S. Power, Chief of the Strategic Air Command, on 29 April 1958, asked the Air Force Chief of Staff what the crisis implied for other aircraft [14]. This led to a second, broader endeavor to examine and develop an understanding of the basic causes of fatigue in order to anticipate and prevent fatigue failures in other aircraft instead of applying costly after-the-fact corrective fixes.

On 12 June 1958, informal approval was given by General Curtis E. LeMay, Air Force Vice Chief of Staff, to ARDC and AMC to proceed with a program identified as "Aircraft Structural Integrity," proposed by ARDC(WADC). The primary objectives of this program were (a) to control structural fatigue in the operational aircraft fleet, (b) to devise methods of accurately predicting aircraft service life, and (c) to provide the design know-how and test techniques required to avoid structural and sonic fatigue problems in future weapons systems. The program, as it developed in scope, was a necessarily unwieldy enterprise which flowed across the responsibility boundaries of the major USAF commands. Directly and indirectly involved by 1959 were all major commands, their subordinate units, 19 weapons systems, at least seven major aircraft manufacturers, and a whole host of subcontractors. Technically, the program involved almost every aspect of aircraft engineering, spilling over into many related scientific areas involving every laboratory at the Wright Air Development Center.

It quickly became clear the structural integrity program required not only additional resources in the form of money,

manpower, and facilities, but also required a commitment from the major commands in the form of a precedence or priority rating to cut across the administrative lines of responsibility already in being. This proved difficult to obtain; however, a policy directive from General LeMay on 19 November 1958 eventually served the same purpose [19]. This directive emphasized the importance of the structural integrity program and called for the complete and active support and cooperation of all Air Force elements. With this support, the various parts of ASIP encountered relatively little difficulty and few administrative obstructions. The rehabilitation of the B-47 and a "Structural Fatigue Certification Program" of most of the then current service aircraft was rapidly planned and implemented. As part of a longer range goal, the Air Force and the aircraft industry jointly sought improvements in design philosophy and technology to meet the ASIP objectives. There were numerous revisions and additions to the original ASIP concepts as put forth in the first official ASIP document in February 1959 [20]; however, the basic objectives established in 1958 remained relatively unchanged.

This does not mean that everything ran smoothly during the development of the Aircraft Structural Integrity Program. From the B-47 crisis in 1958 to the F-111 crisis in 1967, technology affecting aircraft design and design criteria developed rapidly due to the impetus of the ASIP requirements. In addition, the accelerated research created by the immense technological effort being put into the space program in the 1960's contributed mightily to the rapid development of new materials and technology which also spun-off into the aircraft industry. The intellectual climate created by the space program was possibly just as important, popularizing the acceptance of new ideas and the idea of progress. Despite this, acceptance and implementation of newer and usually more expensive and sophisticated design philosophy and technology for the ASIP did not come easily, especially in the aircraft

industry, but often in government circles as well. It is understandable that the aircraft industry has always had a conservative tendency to stick with time tested technology and criteria in aircraft design and manufacture, adopting new techniques only after a complete demonstration that these techniques result in aircraft at least as safe as previous aircraft. In order to accomplish the long range ASIP objectives, it was vital that this normal process be speeded up. The first step in this process would be to define these objectives, agree upon proposed actions, and to assign responsibility for these actions. The second step would be to obtain the understanding and cooperation of the aircraft community in the structural integrity program as it became successively more complex and far-reaching.

The initial ASIP objectives were limited primarily to answering the questions posed by General Power on 29 April 1958 [14], when he stated "I believe it absolutely essential that we learn what we bought in terms of service life in the B-47 and B-52, and what we will buy in the B-58 and B-70." The resolution of this question became the basis for the early part of the structural integrity program. Events moved rapidly from this point as can be seen from the chronology of events shown in Table 1. The Wright Air Development Center (WADC) had already given the question considerable thought and was moving toward some answers so that two days later in a memorandum to Major General M. D. Burnside, Director of Maintenance Engineering for the Air Material Command (AMC), Major General Stanley S. Wray, Commander of WADC, was able to propose a program for investigating aircraft fatigue problems [21]. AMC found the WADC plan a good approach and on 8 May, General Burnside offered financial assistance to fund most of this program. AMC would provide \$600,000 to cover an expanded B-66 low-altitude gust environment program and would provide

TABLE 1
CHRONOLOGY OF KEY ASIP EVENTS

1958	March 13	First two B-47 accidents clearly due to structural failure.
	April 29	General Power asks what B-47 crisis implies for other aircraft.
	May 8	AMC offers to fund large part of Structural Integrity Program.
	May 9	USAF directive to AMC and ARDC for joint Structural Integrity Program.
	May 12	Colonel Taylor identifies six strategic aircraft for structural investigation.
	June 12	General LeMay gives informal approval to Structural Integrity Program.
	June 27	WCLS-TM-58-4 "Detail Requirements for Structural Fatigue Certification Program" published.
	Nov. 19	General LeMay's teletype formally establishes ASIP.
	Dec. 11	Colonel Taylor formally appoints "Team Captain and contact point" for ARDC part in ASIP.
1959	Feb. 16	ARDC-AMC "Program Requirements for the Structural Integrity Program for High Performance Aircraft" published.
	Aug. 11-13	USAF Symposium on Fatigue of Aircraft Structures held at WADC.
	Oct. 5	Hq. USAF letter establishes Aircraft Service Life Requirements.
1961	July 17	ASD Structural Integrity Program Advisory Group (ASIPAG) established.
	Sept.	ASD-TN-61-141 "Detail Requirements and Status Air Force Structural Integrity Program" published.
1962	Nov. 6	ASD ASIP-Industry Advisory Group established.
1968	Jan.	ASD-TR-66-57 "Air Force Structural Integrity Program Requirements" published.
1969	June 12	AF Regulations 80-13 published.
1972	Sept. 1	Mil-Std. 1530 published.
1975	Dec. 11	Mil-Std. 1530A published.
1976	July 16	AF Regulation 80-13 revised.

\$150,000 for flight load recording equipment for six B-47's and six B-52's. In addition, AMC agreed to underwrite the cost of cyclic tests on the B-47 and B-52 [22].

Meanwhile, expansion of the structural integrity program gradually became more formal. On 6 May, Lt. General S. E. Anderson, Commander of the Air Research and Development Command (ARDC), anticipating a directive from Air Force headquarters, suggested that AMC and WADC begin preliminary discussions of a "proposal for an adequate service flight loads survey program for all types of aircraft on a continuing basis" [23]. The objective of this program was to obtain sufficient flight loads data so that:

- (1) If possible, critical failure areas could be pinpointed prior to an actual occurrence in service aircraft.
- (2) In the event an engineering fix is required, an adequate fix could be determined in the shortest possible time.
- (3) Efforts such as service life reductions, and alternate operational missions or tactics could be determined and knowledge of these effects made available for operational command considerations.
- (4) Loading spectra would be available for fatigue testing programs if required.
- (5) More accurate design criteria would be available for follow-on future aircraft.

Specifically, the proposed joint program was to start with certain programs on which WADC was already working, such as an expanded flight load survey, a low-altitude gust survey, and the collection and reduction of data using an eight-channel recorder recently developed under a Center project. ARDC proposed to furnish technical supervision for the overall program

and would bear the cost of necessary development work for instrumentation and data-processing techniques. Research funds, however, could not be used for the procurement of the necessary recorders, their installation and repair, collection and reduction of data, or the operation of data reduction facilities. Another source, such as product improvement funds, would have to be found to fund this portion of the project.

In response to this recommendation, representatives of AMC, WADC, and ARDC met on 7 May to work up an initial program to cover the B-47, B-52, B-58, KC-135 and B-70 aircraft. This preliminary plan also considered the eventual coverage of other aircraft. The expected formal Air Force Directive [24], dated 12 May, called for ARDC and AMC to develop a joint long range program which took into consideration the planned efforts of the National Advisory Committee for Aeronautics (NACA), the other services, educational institutions, and the aircraft industry. The proposal was to furnish a basis for the determination of aircraft fatigue by analytical methods and/or component fatigue cycle testing. Loads imposed on aircraft structures from all conditions of operation such as maneuver, gust, landing, or sonic, were to be considered. ARDC and AMC were to present their recommended program as integrated with the other programs of other agencies involved at an early date.

The program quickly grew and took shape. By 12 May Colonel John P. Taylor, Assistant Chief of the Aircraft Laboratory, had already drafted a program which included specific plans for flight load surveys and static tests on the B-47, B-52, B-58 and KC-135 aircraft, and an outline of the instrument requirements, cost, and probable problem areas [25]. On 19 May, the Air Force and the Boeing Company agreed on a part of the program to determine the structural integrity of the Boeing family of military aircraft. The B-47 analysis effort would continue, while the B-52 and KC-135 would undergo parallel

investigations, inspection, cyclic tests and improved instrumentation. The Boeing inquiry would also include a continuing inspection and surveillance of the C/KC-97 fleet [26]. On 23 May "interceptor type" aircraft such as the F-101, F-104, F-105 and F-106 were added to the program [27]. Evaluation of these vehicles was to depend on three basic actions. A flight test program of one instrumented aircraft would duplicate planned operational missions. Data from these flights would help create a loading spectrum, and the subsequent cyclic fatigue test would indicate whether the aircraft had any structural weak points. Following a presentation of this proposed joint program, General LeMay directed the parties concerned to proceed with the job of repairing the existing aircraft fleet.

A formal amplified version of Colonel Taylor's 12 May outline became the Aircraft Laboratory's Technical Memorandum WCLS-TM-58-4, dated 27 June 1958 [28]. Entitled "Detail Requirements for Structural Fatigue Certification Programs," the memorandum established design fatigue life requirements, expressed in number of flight hours and landings, for all aircraft the program was to encompass. This data represented new design requirements to be included in a forthcoming revision to Specification MIL-S-5700 which would reflect joint USAF-Navy fatigue design requirements. The report also indicated WADC's recommended order of priority covering 18 specific aircraft. This list began with the B-47, the B-52, the KC-135 and the B-70. The last of the 18 were the B-66 and F-89. The program presented a structural development procedure to achieve these goals as shown in Figure 2. Three of the elements in this procedure were already integral parts of the research and development process. The design phase represented the best integration of theory and experience available at the time of conception. This was now to include a fatigue analysis which was to be maintained and revised on a continuing basis. All information from other tests would enable the designers to plan more

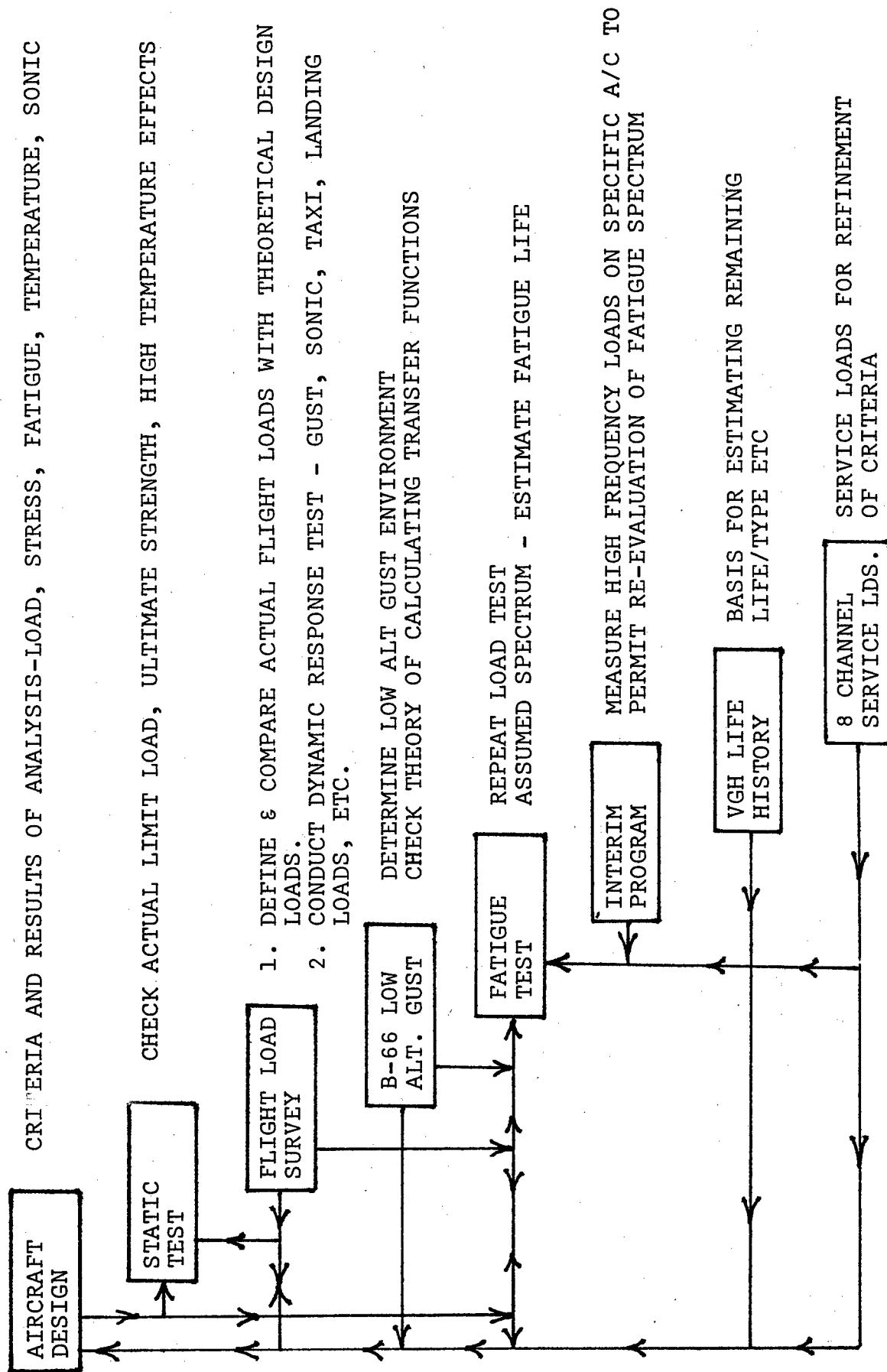


Figure 2. Structural Development Procedure Under WCLS-TM-58-4

accurately and realistically for future aircraft. The static test confirmed that the structure had the actual physical strength to withstand the loads envisioned in the design. The third phase was a flight load survey which would include dynamic response flight test, gust load survey and landing and taxi tests.

The fatigue or cyclic test was to become a standard requirement for all aircraft, rather than an infrequent engineering tool used only when the vehicle developed a structural ailment. Fatigue testing would use the results of the first three steps to create spectra duplicating the stresses of operational use. By compressing years of an aircraft's life cycle into a matter of a few weeks, the fatigue test would help pinpoint areas of critical structural weakness. The service loads recording program encompassed several projects designed to measure the actual loads incurred by in-service aircraft usable as a basis for estimating remaining aircraft life. Finally, a sonic fatigue prevention program involving careful inspection, maintenance, and modification of aircraft subject to sonic stresses was included in the memorandum to prevent minor sonic damage from becoming a flight hazard.

WCLS-TM-58-4 also brought into focus the previous, scattered efforts to acquire knowledge and establish criteria concerning fatigue, and established general requirements for an overall fatigue evaluation. The details of application might vary from one aircraft to another and there might be later additions to the list, but it provided a starting point for solving the fatigue problem. Future reports would modify this program, but the basic approach remained relatively unchanged. Organization and publication of this material between March and June 1958 reflected, in the words of General Burnside, "a tremendous amount of constructive work in a very short space of time," [29]. He added, "It would be my personal expectation that there will be some changes in this program

as we learn more about the general subject of fatigue failures. Nevertheless, the program as it now stands represents the collaborative efforts of the best people in the business and I feel that we should start out on the program as it now stands."

Few doubted the importance of the program, but establishing high enough priority ratings to get the program rolling proved to be something of an administrative headache, largely because the inquiry cut across so many commands. In addition, funds and personnel were necessary to accomplish the projects and tasks such as the static and fatigue tests on each type airplane. WADC alone required an additional 149 personnel, over one million dollars for FY-1959, and about three million dollars per year for FY-1960, 1961 and 1962 [30]. On 19 November 1958 the program received the necessary formal backing, consisting of the directive from General Curtis E. LeMay, the Vice Chief of Staff of the U.S. Air Force [19]. (A copy of this directive is included as Appendix A). Technical direction of the program was given to ARDC and all affected individuals and organizations were directed to give the program their complete and wholehearted support. Publication of the directive formally established ASIP as a program and cleared the field for an all-out attack on the problem of metal fatigue.

SECTION V

ASIP - THE FORMATIVE YEARS

So extensive had been the effort bearing on the B-47 problem and on the basic structural criteria problem, that little time was spared for "formalization" of the structural integrity program until that effort was well on the way to a satisfactory completion. When the ARDC officially acquired responsibility for the program as a result of General LeMay's 19 November directive, WADC became the command's action agency. This was formalized by appointing Colonel John P. Taylor, Assistant Chief of the Aircraft Laboratory, as the "team captain and contact point" to control the technical side of the investigation [31].

This appointment merely confirmed the role he had been playing for months, as Colonel Taylor had been in charge of the WADC portion of the Air Force response to the B-47 crisis since its beginning. In addition to technical direction of this effort, Colonel Taylor had proven himself indefatigable in preparing an effective corrective program and in making a series of presentations to individuals at all levels in order to obtain widespread support of the effort needed to correct the condition. As chief spokesman for the technical aspects of the inquiry, he had traveled widely and steadily, representing the Research and Development Command in explaining the need for the program to the Bureau of the Budget personnel, Department of Defense officials, the top men in Air Force Headquarters, and individuals in the various commands affected by the threat of structural fatigue. Many persons played important roles in the ASIP development, and the history of ASIP is to a large degree the history of the contributions of these individuals to a program in which they believed very strongly. Colonel John P. Taylor's energetic role in the B-47 rehabilitation program and in the formation of the aircraft structural integrity program, however, certainly

deserves special recognition. More than any other single person, Col. Taylor laid the groundwork and convinced people at all levels of the type of program that was needed to solve the aircraft fatigue program.

Just as Col. Taylor had been instrumental in getting WCLS-TM-58-4 written and published, he was also instrumental in publishing the first report which formally documented ASIP. This document, titled "ARDC-AMC Program Requirements for the Structural Integrity Program for High Performance Aircraft," was dated 16 February 1959 [20]. Prepared jointly by ARDC and AMC, it divided the work of ASIP into eleven sub-program areas and indicated the basic responsibility of each Command in these sub-areas. These eleven sub-areas were:

- 1 Static Test
- 2 Flight Load Survey
- 3 Fatigue Test
- 4 Low Altitude Gust Environment
- 5 Mission Profile Data
- 6 Interim Service Load
- 7 VGH Life History Recording
- 8 8 Channel Service Load Recording
- 9 Sonic Fatigue
- 10 High Temperature Structure
- 11 Design Criteria

The document also contained comprehensive programs and resource requirements for both ARDC and AMC and set down schedules for load surveys, static tests, fatigue tests and VGH recorder installations by aircraft type and model. On 18 May 1959, General LeMay formally approved this joint program and directed its "implementations on a priority basis" [32]. General LeMay further commended the cooperative action by which the two Commands had transformed the "chaos" of the original B-47 crisis into an "orderly program which has

provided the answers to our immediate problems and promised the long term solution as well."

Additional indication that the structural integrity inquiry had come a long way in one year's time was given when Colonel Taylor embarked on a new series of presentations in April 1959. These presentations carried him from his own commander, General Wray, through step-by-step channels to General LeMay. In each briefing at each command level along the way, Colonel Taylor aired the notion of a structural fatigue symposium, to be held at the Wright Air Development Center from 11 to 13 August 1959. The idea was received favorably everywhere along the presentation trail, and Colonel Taylor began preparing for the event. The purpose of the symposium was to acquaint management and technical personnel of the airframe manufacturers, airlines, government organizations, and academic groups with the structural integrity program and to emphasize the importance of structural fatigue. Perhaps more important, the meeting would afford an opportunity for pooling available knowledge on the general subject of fatigue in aircraft and aerospace structures, and would promote the exchange of philosophic and technical information. The conference was extremely well attended, with over 600 delegates representing the three services, the National Aeronautics and Space Administration, the Advanced Research Projects Agency, the aviation industry, commercial airlines and university research organizations. British and Canadian delegates were also in attendance. The conference marked as clearly as any other event, the status, the accomplishments and the promise of the structural integrity program in the summer of 1959.

From 1959 to 1961, the Aircraft Structural Integrity Program proceeded according to the ARDC-AMC plan, as the Air Force initiated and re-oriented the necessary research and development and the service engineering required to evaluate the

structural capability and life expectancy of USAF aircraft. As the program evolved, it became evident that some of the phases used to subdivide the structural integrity efforts were not sufficiently definitive to adequately organize and document the efforts. As a result, some important aspects of the work were sometimes forced into a sub-phase of the closest associate phase, and the program was subjected to extensive review in 1961 by engineering and weapons system personnel of ASD. (As a result of a major realignment of Air Force Command between 1959 and 1961, ARDC and AMC had been realigned into the Aeronautical Systems Division (ASD) and the Air Force Logistics Command (AFLC), respectively.)

This review resulted in the publication of a new report establishing updated requirements for the ASIP in order to give the program the benefit of experience and events [33]. Titled "Detail Requirements and Status, Air Force Structural Integrity Program," ASD Technical Note 61-141, the report merged the original eleven phases of ASIP into five phases, as shown in Figure 3, which proceeded more or less chronologically. A flow diagram of these five phases; Design Information, Initial Design Analysis, Testing, Final Structural Integrity Analysis, and Actual Operational Use, is shown in Figure 4. The report was very comprehensive, as it also included considerable detail on the status of the ASIP phases and the application of these phases to each weapons system in the inventory. This included such information as the time phasing of the ASIP plan, the status of the static and fatigue test, the VGH life history recorder requirements, and the status of the service loads program for each aircraft system.

Further formal documentation of ASIP did not occur until 1966 when SEFS-TM-66-1, "Detail Requirements Air Force Structural Integrity Program," [34], was published. Publication of this document actually began in 1965 with SEFS-TM-65-1. However, due to delay caused by many revisions, this TM was

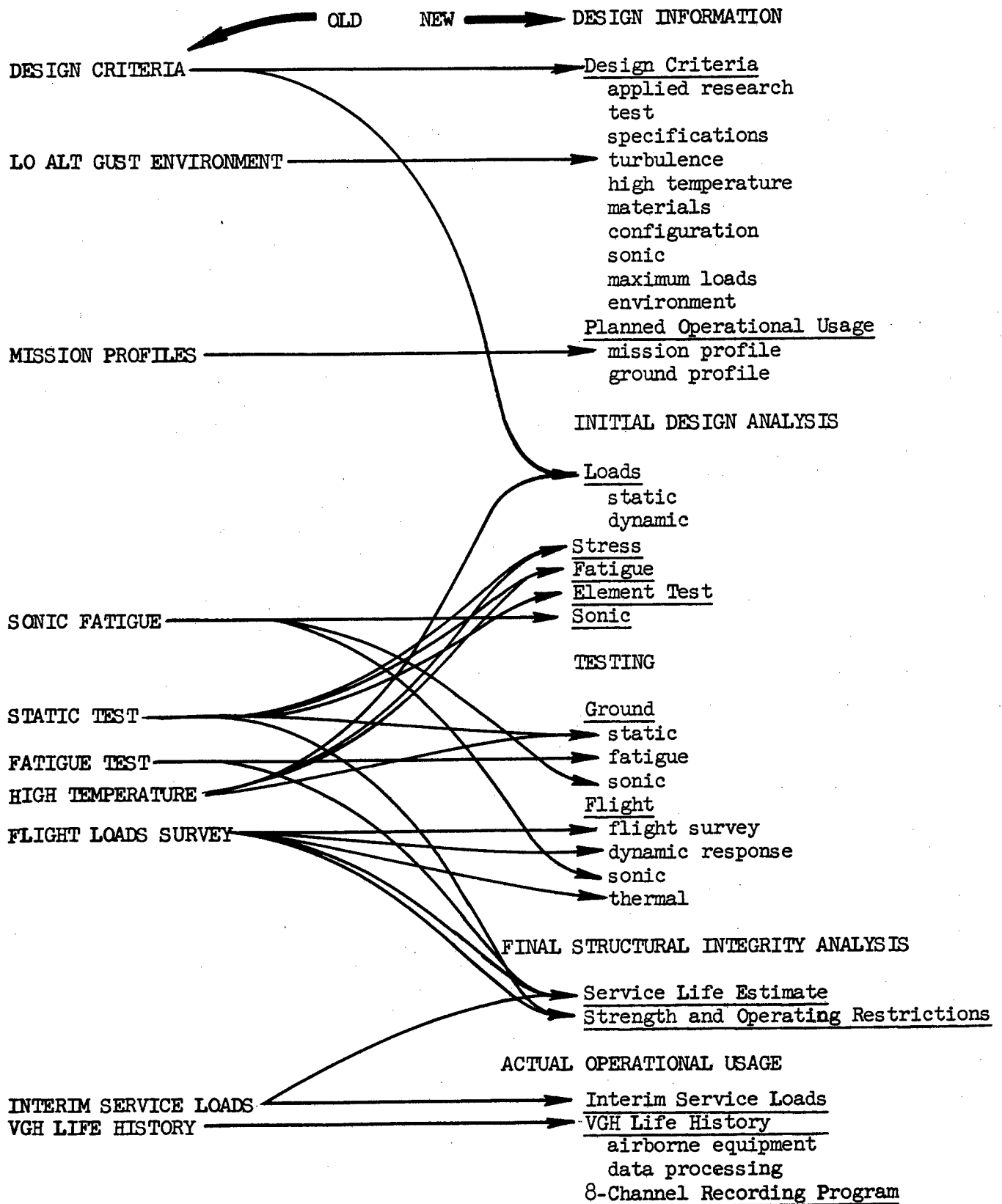


Figure 3. Elements of the AIR FORCE STRUCTURAL INTEGRITY PROGRAM (From ASD-TN-61-141)

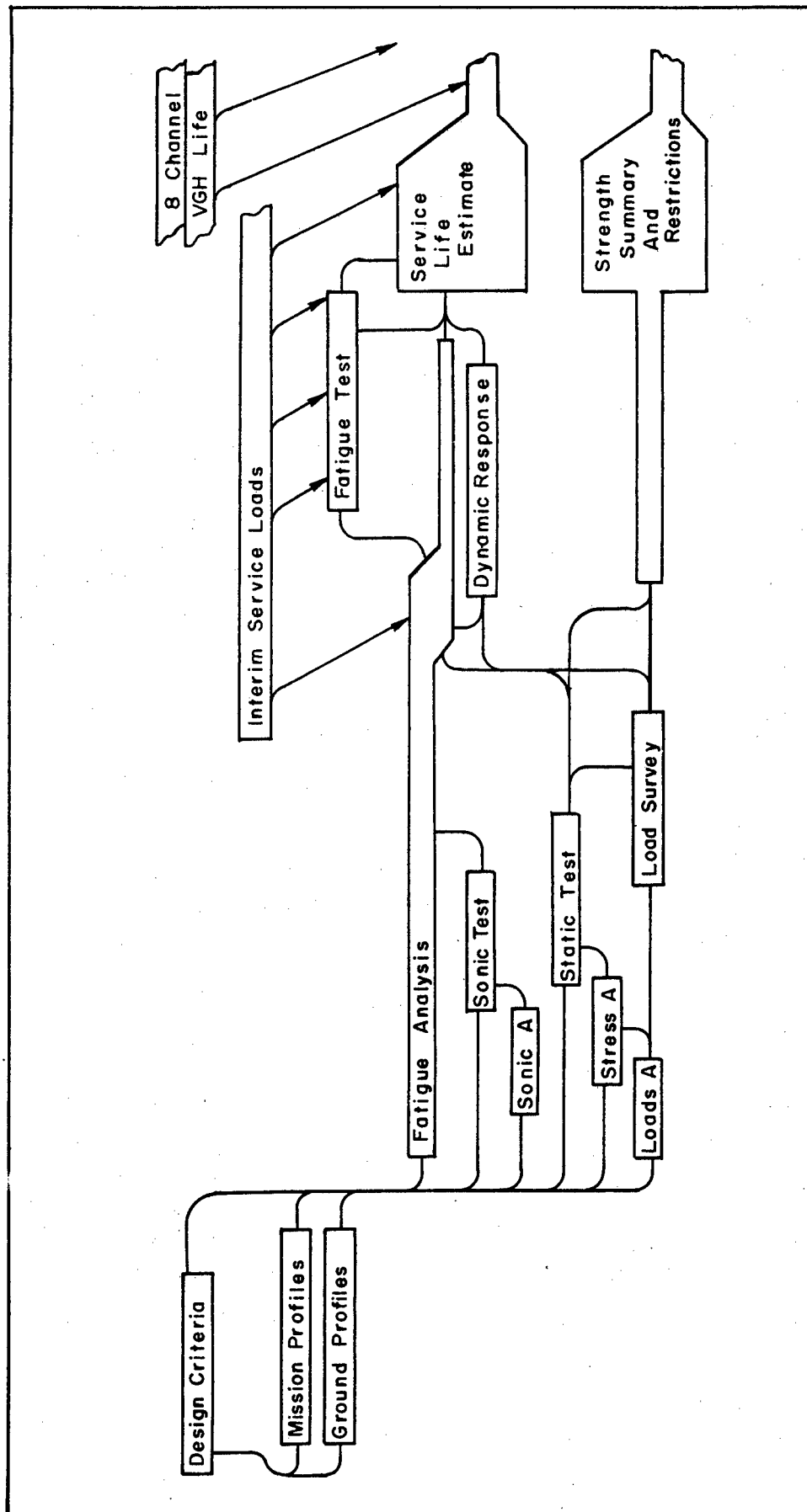


Figure 4. ASIP Flow Diagram (From ASD-TN-61-141)

eventually published in June 1966. At this time a decision was made to convert the TM into a Technical Report for more wide-spread dissemination [35]. This process took more than a year, and the final version of the TR was published in January 1968 [36]. The two documents are essentially the same, with two changes. The first change was to make the language of the TR conform to accepted practice. The TM had been written in a "directive" sense in many areas in which the USAF described its requirements to industry, and this was changed to a "reporting on how things are or should be," common to technical report writing. The second change was to acknowledge improvements in the flight load recorder area leading to ultimate replacement of oscillographic recorders. Based on this, TR-66-57 placed VGH and Multichannel recording under a "Life History Program." The Service Loads Recording Program was covered under the Multichannel Life History Recording Program discussion. The Exceedance Counter Program was placed under the Industrial Aircraft Usage Program. The Flight Dynamics Laboratory's Maneuver Loads Program was given separate coverage as the "Multichannel Maneuver Loads Recording Program." Table 2 and Figure 5 illustrate the ASIP phases and the ASIP flow chart as given in ASD-TR-66-57. Additional coverage in TR-66-57, not included in the ASIP documents, was directed to sections on the concepts of fail-safe or damage-tolerant structures, safe-life, and scatter factor. This coverage was a result of on-going research as well as intense discussions between industry and government on the usage of these concepts.

The ASIP reports contained technical requirements for the Aircraft Structural Integrity Program, supplementing the detailed structural specifications for Air Force aerospace vehicles. However, they did not contain authority for implementing such a program. This was finally accomplished on 12 June 1969 with the publication of AF Regulation 80-13. This regulation

TABLE 2
ASIP REQUIREMENTS BY PHASES*

DESIGN INFORMATION (PHASE I)

Design Criteria
Planned Operational
Mission Profiles
Ground Profiles

INITIAL DESIGN ANALYSIS (PHASE II)

Loads Analysis
Stress Analysis
Fatigue Analysis
Flutter Analysis
Sonic Loads
Element Tests

TESTING (PHASE III)

Ground Tests
Static Tests
Fatigue Tests
Flutter Tests
Sonic Tests

FLIGHT TESTS

Flight Load Survey
Dynamic Response Tests
Thermal Flight Tests
Flight Flutter Tests

FINAL STRUCTURAL INTEGRITY ANALYSIS (PHASE IV)

Strength Summary and Operating Restrictions Analysis
Service-Life Analysis
Parametric Fatigue Analysis

ACTUAL OPERATIONAL USAGE (PHASE V)

Life History Program
VGH Life History Recording Program
Multichannel Life History Recording Program
Individual Aircraft Usage Program
Exceedance Counter Program
Multichannel Maneuver Loads Recording Program

*From ASD-TR-66-57

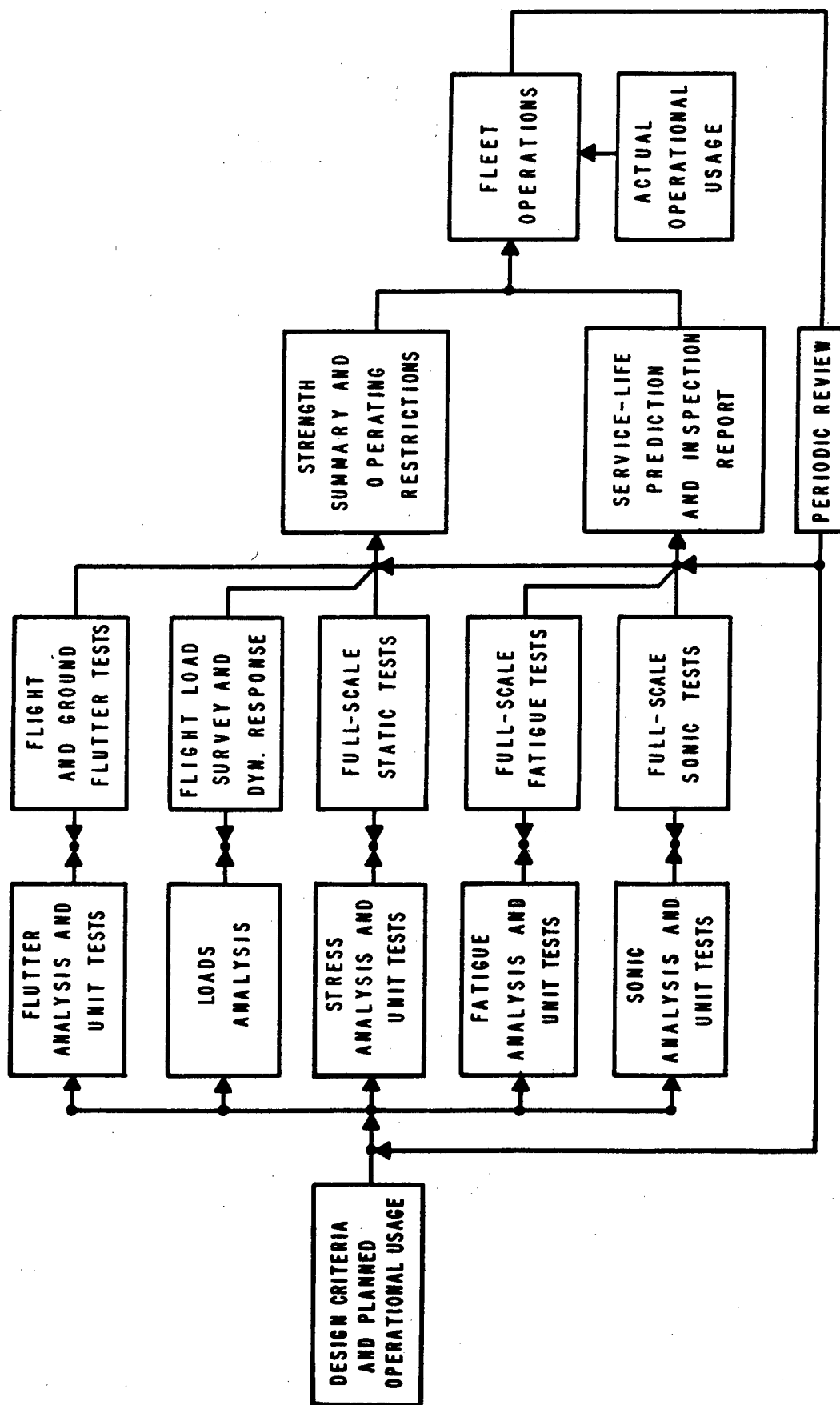


Figure 5. ASIP Flow Diagram (From ASD-TR-66-57)

stated the policy, procedures, and responsibilities to be followed by the appropriate commands in conducting and implementing ASIP requirements. AF Regulation 80-13 added a phase VI, Inspections, to the program and assigned responsibilities for the ASIP requirements to Headquarters, USAF, Air Force System Command (AFSC), Air Force Logistics Command (AFLC), and to the using commands (see Table 3). With the publication of this directive, ASIP became an official requirement for all aircraft systems currently in concept, definition, or acquisition phases as well as all future aircraft systems developed by the Air Force.

The ASIP requirements were also directed to be applied as necessary to assure flight safety and to achieve the required service life for current operational front line aircraft, aircraft systems not developed by the Air Force, and aircraft modified and directed to new missions. An ASIP master plan was required to be included as part of the procurement documentation for each weapon system in the definition and acquisition phase. This master plan was required to span the entire life of the aircraft from contract definition through operational phase-out.

The ten research-filled years from June 1958 to June 1969 had seen ASIP grow from a concept begun as a stop-gap emergency program to an officially directed Air Force program designed to prevent crises such as occurred with the B-47. This, however, was destined not to be, as two additional crises occurred in the near future. These crises included fatigue problems with two of the newest aircraft in the Air Force inventory, the F-111 fighter-bomber and the C-5 transport. Both required the use of almost every bit of technology available to the aircraft engineer, and both came under heavy political pressure to cancel the aircraft program. Both systems were important to the national defense, although not as important as the B-47 during its lifetime. Nevertheless, there was a close parallel,

TABLE 3
ASIP PHASES*

ASIP RESPONSIBILITIES FOR NEW AF SYSTEMS			
ASIP PHASES	AFSC	AFLC	USING COMMAND
I Design Information			
Design Criteria	I		
Operational Usage	I		D
Mission Profile	I		D
ASIP Master Plan	I	(I)	D
II Initial Design Analysis			
Load analysis	I		
Stress Analysis	I		
Fatigue Analysis	I		
Flutter Analysis	I		
Sonic Fatigue Analysis	I		
III Testing			
Ground Tests	I		
Flight Tests	I		
IV Final Structural Integrity			
Strength and Operating Restrictions Report	I		
Service-Life Analysis	I		D
Parametric Fatigue Analysis	I		D
V Actual Operational Usage			
Procure and Install Recorders	I	M	
FWD Recorder Magazines, Supporting Data, Etc.	I		D
Individual Aircraft Usage Program	I	(I)	D
Strength and Operating Restriction Report	I	M	D
Service-Life Analysis	I	M	D
Parametric Fatigue Analysis	I	M	D
Exceedence Counter Program (If Required)	I	M	D
VI Inspections		I	(I)
NOTE: I—Initiate and conduct tests and analyses, prepare reports and/or initiate contracts. M—Maintain and revise reports, or continue tests and analyses, and/or continue contracts. D—Provide and update data. (I)—Initiate if not previously initiated.			

*From AFR 80-13, 12 June 1969

particularly between the F-111 and the B-47. As a result of the crash of an F-111A in December 1969 due to a fatigue failure in the wing pivot fitting, a two-phase recovery program was implemented. Phase I was divided into (a) an extensive test program to collect basic material crack growth data and develop a flaw growth model to calculate a safe operating interval, given an initial flaw and flaw size, (b) a cold proof test program to demonstrate that critical size flaws were not present in critical forgings, and (c) improved non-destructive inspection techniques (NDI) for use in a reinspection program. Phase II of the F-111 recovery program was accomplished by incorporating refined NDI techniques during aircraft production and by establishing final inspection intervals based on a fracture mechanics program. Phase I was a series of short term actions designed to permit operations of the aircraft to 80% of its designed capability, allowing the F-111 fleet to continue flying, while Phase II included the long term actions necessary to permit operations to the airplane's full design capability. These actions led to the development and acceptance of additional design tools such as linear elastic fracture mechanics techniques, damage-tolerant structural concepts, risk assessment of structural failure, and considerable improvement in NDI techniques and procedures [37]. All of these tools would be incorporated into the next revision of ASIP documentation.

This next revision of the formal ASIP documentation occurred in 1972 when MIL-STD-1530 [38] was published. This military standard replaced the previous ASIP technical reports in defining the requirements necessary to achieve structural integrity of USAF airplanes and in specifying methods of contractor compliance. MIL-STD-1530 divided ASIP requirements into five interrelated functional tasks (Table 4). The first three tasks were almost identical with the first three ASIP

TABLE 4
ASIP TASKS*

Task I	Task II	Task III	Task IV	Task V
Design Information	Design Analyses And Development Tests	Full Scale Testing	Fleet Management Data Package	Fleet Management
ASIP master plan	Material and joint allowables	Static test	Final analyses	Loads/environment spectra survey support
Structural design criteria	Loads analysis	Damage tolerance tests	Strength summary	Service monitoring program
Fracture and fatigue control plan	Temperature analysis	Fatigue tests	Parametric analysis	Service inspection maintenance and repair
Selection of materials, processes and joining methods	Stress analysis	Sonic fatigue tests	Instrumentation and data recording provisions	Structural performance records
Planned operational usage	Damage tolerance analysis	Flight and ground loads survey	Service inspection and maintenance control	
	Fatigue analysis	Flutter tests		
	Sonic fatigue analysis	Flight flutter tests		
	Vibration analysis	Loads/environment spectra survey		
	Flutter analysis			
	Nuclear weapons effects analysis			
	Nonnuclear weapons effects analysis			
	Design development and preproduction design verification tests			

* From Mil-Standard 1530, 1 September 1972)

phases as previously defined, while the last two tasks differed considerably from the previous ASIP phases. The first three tasks, Design Information, Design Analysis and Development Tests, and Full Scale Testing, covered the requirements that the contractor must meet to provide airframe structures which have the required safety and durability throughout their design service life. Task IV (Fleet Management Data Package) required the contractor to generate the data necessary to manage fleet operations in terms of inspections, modifications, and damage assessments. Task V (Fleet Management) was to be primarily the responsibility of the Air Force with the minimum practical amount of contractor assistance. Under this task, the Air Force would track all operational aircraft throughout the life of the fleet to determine actual service usage and the potential impact of this usage on estimated crack initiation times, crack growth rates, and inspection and maintenance requirements.

An important new requirement contained in MIL-STD-1530 was the requirement for an ASIP master plan for each aircraft system. This plan was to be provided as part of the response to the request for proposal for each weapon system. It was to include a specific approach for the accomplishment of each ASIP task throughout the life cycle of the aircraft. The contractor was also to prepare a fracture and fatigue control plan, obtain Air Force approval of the plan, and conduct a fracture and fatigue control program in accordance with the military standard and specifications. Additional emphasis was placed on damage tolerance design concept/material/weight/cost trade studies to be performed during the early design phases to obtain a low-weight, cost-effective design. Other new sections in the ASIP emphasized the selection of materials, manufacturing processes, joining methods, and documentation of the rationale used for their selection. Sections were also added requiring the contractor to perform both nuclear and non-nuclear weapons effect analyses in accordance with detail requirements contained in design handbooks and specifications.

The requirements added to MIL-STD-1530 generally had been tried and proven in the F-111 recovery program. The techniques involved were quite sophisticated, but they offered the contractor the necessary tools to substantiate the structural integrity (airframe strength, rigidity, damage tolerance, durability, and service life) of his airframe structure. The standard became even more comprehensive when it was updated in 1975 as MIL-STD-1530A [39]. The fatigue and fracture control plan was replaced by a damage tolerance control plan and a durability control plan. The damage tolerance control plan required basic fracture data to be obtained, a fracture critical parts list to be established, and nondestructive inspection requirements to be established. The durability control plan stated essentially the same requirements for durability critical parts. Durability critical parts were envisioned as those parts that were expensive to replace. A new section required the contractor to comply with the detail requirements to design for chemical/thermal environment spectra as specified. The tasks in MIL-STD-1530A were only slightly different from those in MIL-STD-1530 (See Table 5), but flow charts of Tasks I, II, III, IV, and V (Figures 6, 7 and 8) were added to the standard to help explain the interrelationship of the functional tasks. An additional figure was added (Figure 9) to illustrate how test results and analyses could disclose potential problems and lead to corrective actions and, if necessary, to production or force modifications. This chart, in effect, summarizes the purpose of the Aircraft Structural Integrity Program.

Shortly after MIL-STD-1530 was revised, AF Reg. 80-13 was also revised [40] to bring it into line with the requirements set forth in the MIL-STD. The revision to the regulations dropped all technical requirements and descriptions of ASIP, leaving that to the MIL-STD. It concentrated only on defining the policy and responsibilities and procedures to be followed by the appropriate commands in establishing, implementing, and

TABLE 5
ASIP TASKS*

TASK I	TASK II	TASK III	TASK IV	TASK V
DESIGN INFORMATION	DESIGN ANALYSES AND DEVELOPMENT TESTS	FULL SCALE TESTING	FORCE MANAGEMENT DATA PACKAGE	FORCE MANAGEMENT
ASIP MASTER PLAN	MATERIALS AND JOINT ALLOWABLES	STATIC TESTS	FINAL ANALYSES	LOADS/ENVIRONMENT SPECTRA SURVEY
STRUCTURAL DESIGN CRITERIA	LOAD ANALYSIS	DURABILITY TESTS	STRENGTH SUMMARY	INDIVIDUAL AIRPLANE TRACKING DATA
DAMAGE TOLERANCE & DURABILITY CONTROL PLANS	DESIGN SERVICE LOADS SPECTRA	DAMAGE TOLERANCE TESTS	FORCE STRUCTURAL MAINTENANCE PLAN	INDIVIDUAL AIRPLANE MAINTENANCE TIMES
SELECTION OF MAT'L'S, PROCESSES, & JOINING METHODS	DESIGN CHEMICAL/THERMAL ENVIRONMENT SPECTRA	FLIGHT & GROUND OPERATIONS TESTS	LOADS/ENVIRONMENT SPECTRA SURVEY	STRUCTURAL MAINTENANCE RECORDS
DESIGN SERVICE LIFE AND DESIGN USAGE	STRESS ANALYSIS	SONIC TESTS	INDIVIDUAL AIRPLANE TRACKING PROGRAM	
	DAMAGE TOLERANCE ANALYSIS	FLIGHT VIBRATION TESTS		
	DURABILITY ANALYSIS	FLUTTER TESTS		
	SONIC ANALYSIS	INTERPRETATION OF & EVALUATION OF TEST RESULTS		
	VIBRATION ANALYSIS			
	FLUTTER ANALYSIS			
	NUCLEAR WEAPONS EFFECTS ANALYSIS			
	NON-NUCLEAR WEAPONS EFFECTS ANALYSIS			
	DESIGN DEVELOPMENT TESTS			

*From Mil-Standard 1530A, 11 December 1975

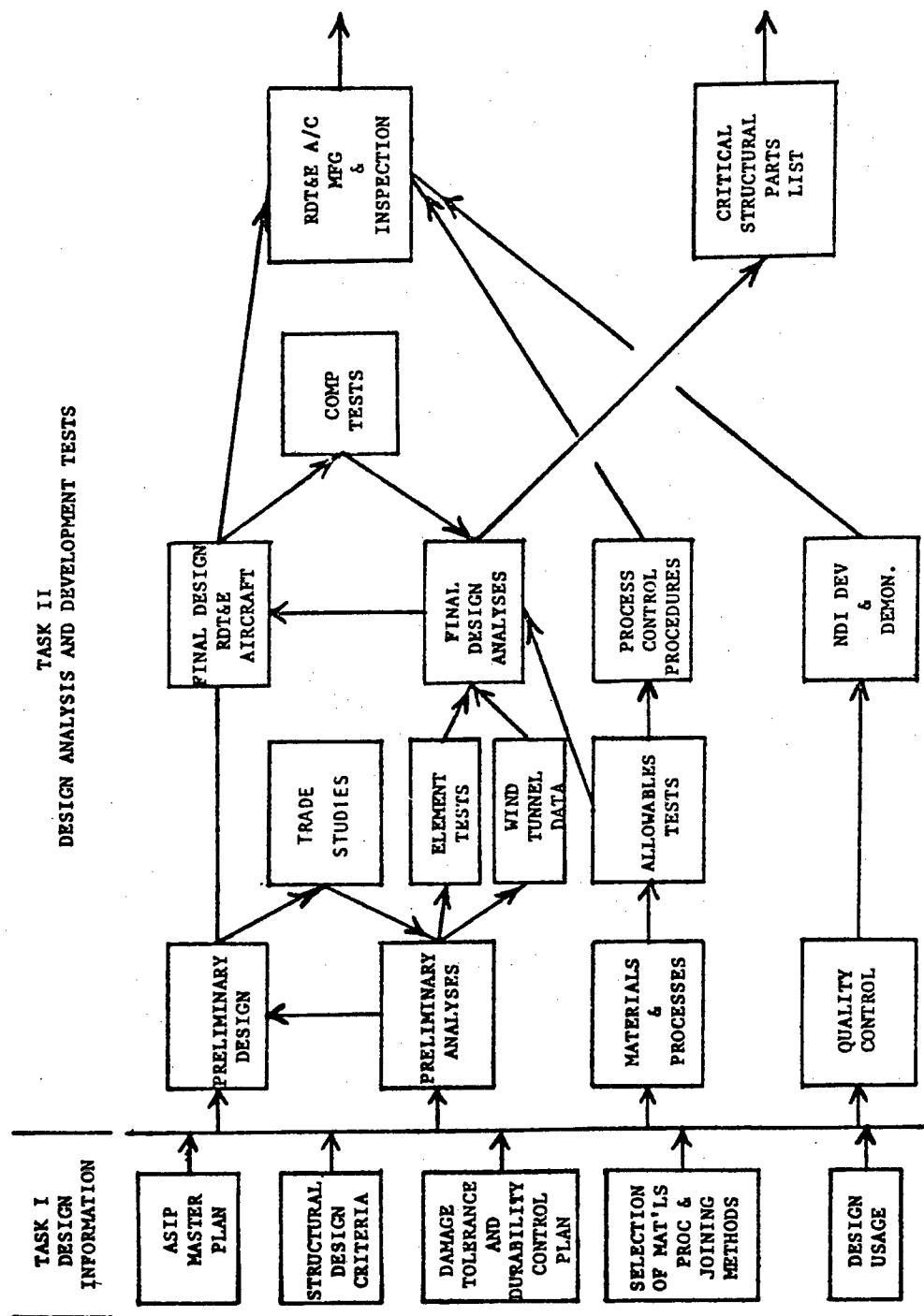


Figure 6. ASIP Flow Diagram of Tasks I and II
(From Mil-Standard 1530A, 11 December 1975)

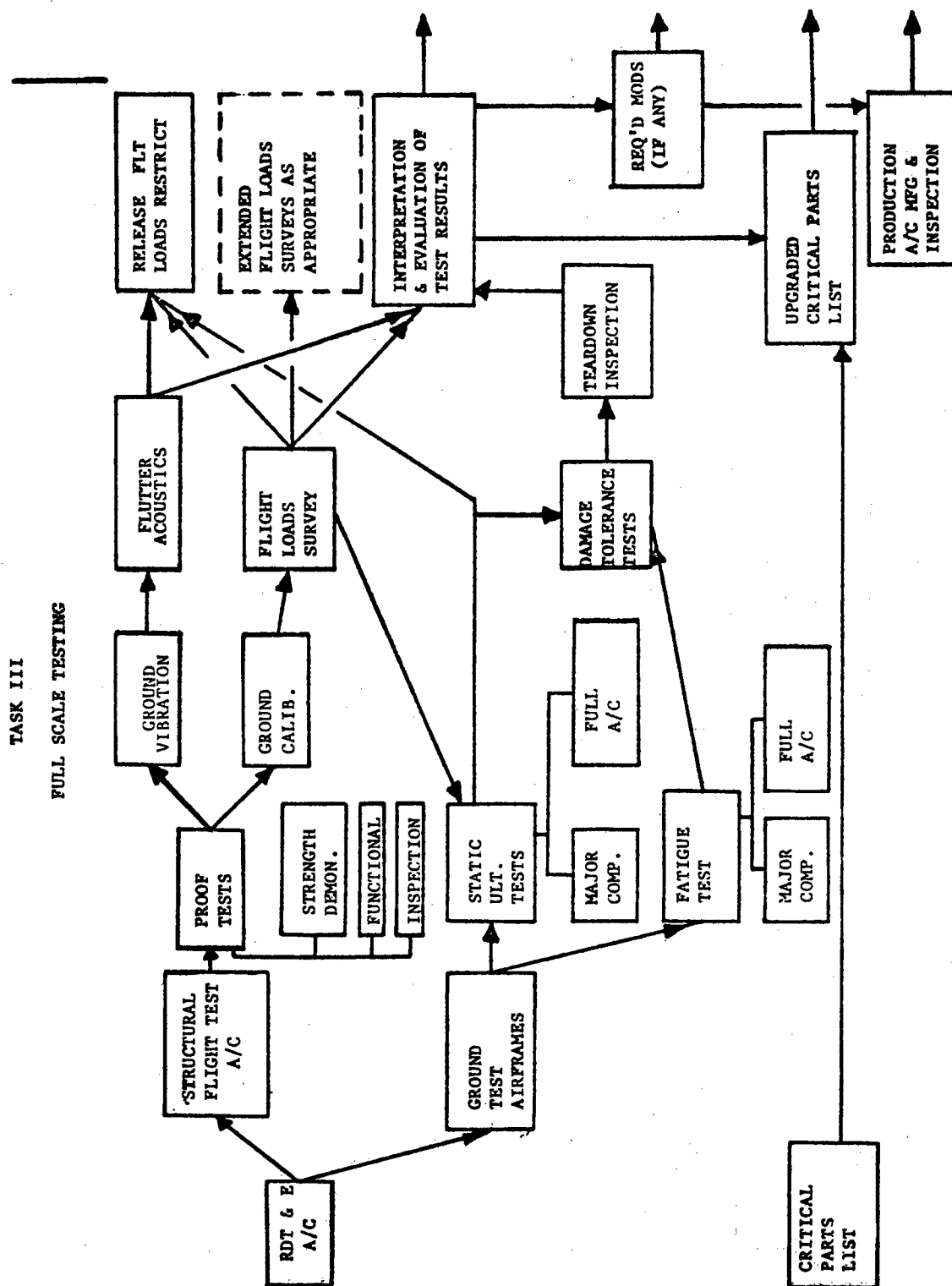


Figure 7. ASIP Flow Diagram of Task III
(From Mil-Standard 1530A, 11 December 1975)

TASK IV - FORCE MANAGEMENT DATA PACKAGE & TASK V - FORCE MANAGEMENT

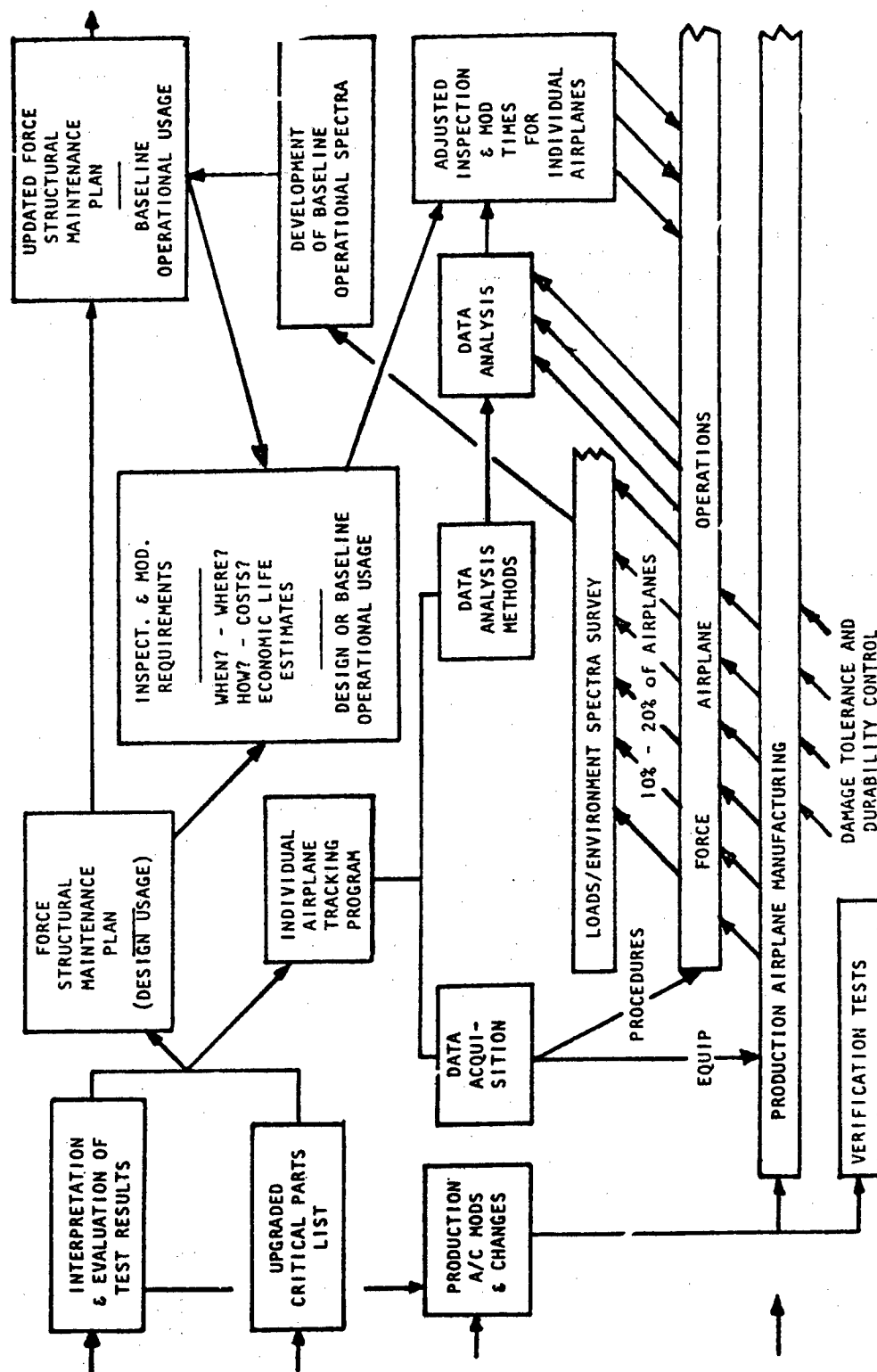


Figure 8. ASIP Flow Diagram of Tasks IV and V
(From Mil-Standard 1530A, 11 December 1975)

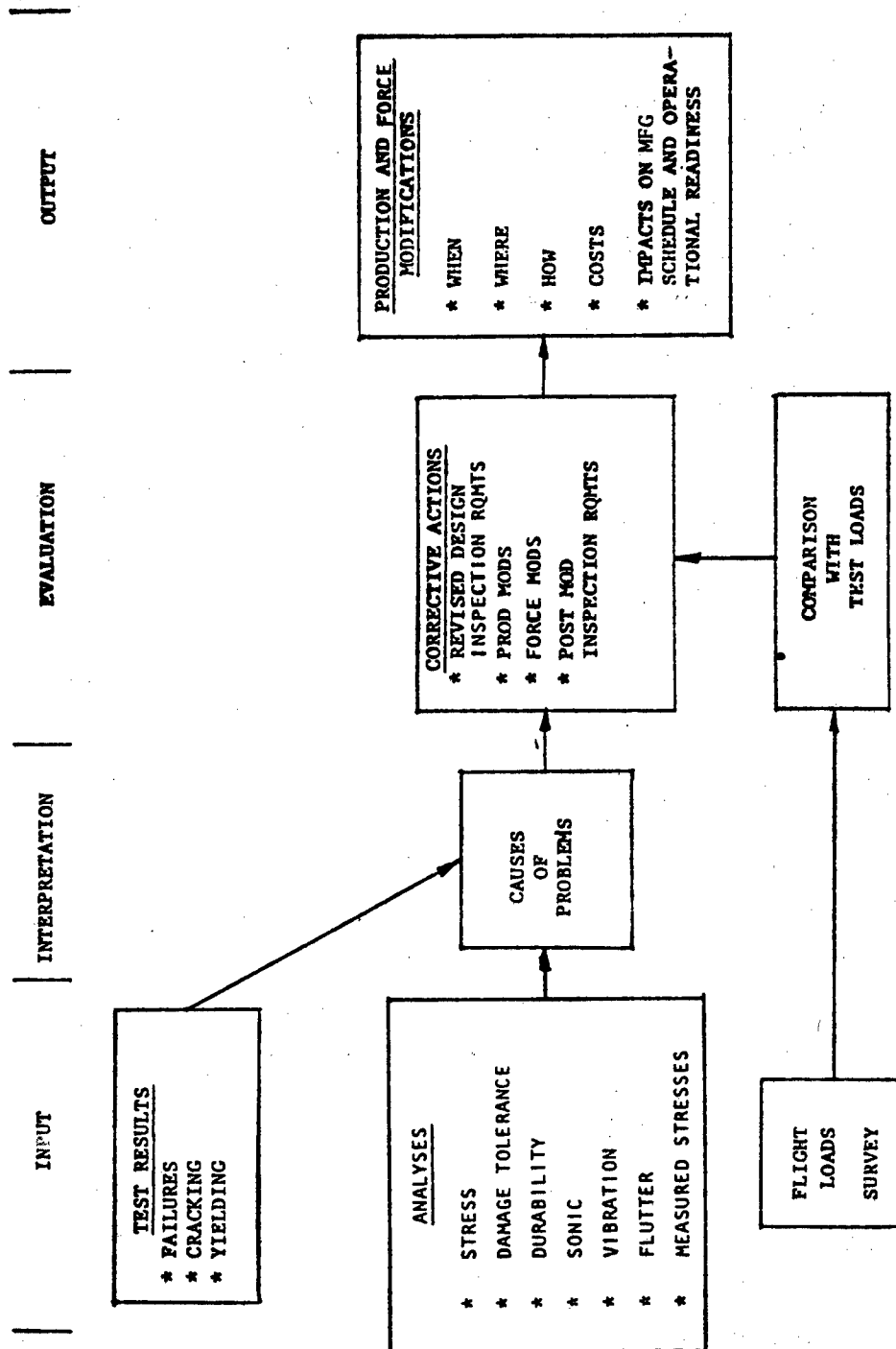


Figure 9. Interpretation and Evaluation of Test Results
(From Mil-Standard 1530A, 11 December 1975)

utilizing the ASIP. A new section required an ASIP manager to prepare an ASIP master plan for each aircraft system being developed or used by the USAF. Assignment of ASIP management responsibility and responsibilities of the ASIP managers were outlined. Responsibilities of all Air Force commands and agencies were repeated. The Air Force Systems Command (AFSC) was charged with the responsibility of maintaining and revising MIL-STD-1530 and the necessary military specifications to reflect technological advances and improvements, and to obtain Air Force Logistics Command (AFLC) coordination and Hq. USAF approval for revision to MIL-STD-1530. AFSC was responsible for appointing ASIP managers on each aircraft system being acquired until program management responsibility was transferred to AFLC at which time AFLC was required to appoint an ASIP manager. AFLC was responsible for establishing and operating the Aircraft Structural Integrity Management Information System (ASIMIS). AFSC was responsible for planning, developing, and managing the structural data collection program and the required computer applications software to be compatible with the ASIMIS as required.

The two major documents, MIL-STD-1530A (11 December 1975) and AFR-80-13 (16 July 1976), updated to reflect the changing design philosophies in government and industry, provide the foundation for the ASIP at the present time. After a long, slow start, the program can be said to be fully active. ASIP master plans have been published for most active aircraft systems. Data is being recorded, analysed and collected by the ASIMIS. Force Management is an active part of everyday Air Force life. Only time will tell how effective the present program is in preventing crises such that which necessitated the B-47 recovery program and in helping to achieve the service life capability desired for present Air Force aircraft

SECTION VI

FATIGUE LIFE REQUIREMENTS

The idea of a required service life is central to ASIP. In fact, AF Regulation 80-13 begins by defining required service life and service life capability. Required service life is defined as the total number of operating hours of a specified mission spectrum throughout which an aircraft structure must be capable of operating safely and economically to satisfy the programmed use of the mission-design-series aircraft force. Service life capability is defined as the total number of operating hours of the specific mission spectrum through which an aircraft structure has been determined by test and analysis to be capable of operating safely and economically.

A design service life had not been specified for aircraft procured through the 1950's. Thus, when ASIP began, little information had been gathered to indicate what the Air Force considered an adequate service life to be. The information that was available was based primarily on full scale fatigue tests of USAF fighter aircraft between 1952 and 1958. This began with the loss of six F-89 aircraft in a short time period wherein in-flight loss of wings occurred. The fatigue capability of the wing-to-fuselage fitting was questioned, and as part of the investigation of this service problem, a full scale wing fatigue test was conducted at WADC. Although the fatigue life of this fitting was not directly responsible for the service accidents, the tests revealed that this fitting had a service life of approximately only 135 hours. If other structural problems had not required the grounding of all F-89 aircraft, this fitting would have soon caused a fatigue problem. It was necessary to develop a redesigned wing-to-fuselage attach fitting to obtain an acceptable service life. This redesigned fitting was proven by a full scale fatigue test for approximately 5,000 hours of service life.

The next fatigue problems occurred with the F-84 aircraft. From 1952 to 1954, approximately 61 cases of rear spar cracking due to fatigue were encountered in the F-84E and G series plus a large number of skin failures on the D, E and G series. As a result of these service failures, the straight wing F-84 series wing fatigue tests were conducted and satisfactory fixes were verified to extend the service life of these aircraft to 3,000 hours. This service life goal was deemed sufficient to phase them out of the inventory. During the course of the tests to cure the rear spar crack and skin crack occurrences, it was found that the F-84G series was limited to a service life of approximately 1,200 hours by the front spar which could fail, causing loss of the wing. It was therefore necessary to develop a fix for the front spar, and to ground F-84G aircraft at 1,200 hours until this fix was installed.

With the service history of the straight wing F-84 series as a background, the contractor of the F-84F attempted to design approximately 5,000 hours of life into the airframe. With this approach, a full scale wing fatigue program was undertaken at WADC as a follow-on to the normal structural test program on this airplane. This test wing was subjected to approximately 8,000 cycles of test load ($g = 8.67$ limit) before a significant failure occurred. This approximate 4,000 hour service life was considered satisfactory.

In 1955, as a result of several F-86F aircraft accidents involving in-flight wing loss, fatigue of the main wing attach fitting was suspected as a contributing cause. A service-wide inspection of all F-86A, B, C, D, E, and F series was instituted to inspect for cracked fittings. Of all aircraft inspected, 515 were found to have cracked fittings. Coincident with this inspection, a full scale wing fatigue test was conducted at WADC to see if the wing attach fitting was fatigue critical and if so, develop the necessary rework to extend the service life until phase-out. This test indicated fittings could crack at

approximately 600 hours of service usage, and the exact service failure was duplicated. A reinforcement was developed to prevent this crack from progressing and to extend the service life of these aircraft to approximately 2,500 to 3,000 hours, which appeared adequate. In addition, a redesigned fitting was provided by the contractor for any future production.

In 1956, a full scale wing fatigue program was authorized as a follow-on to the F-101A structural test program. The results from this first test indicated the F-101A series aircraft had approximately a 500 hour service life. Since it was obvious that this was not adequate, wing rework was incorporated to extend this life. Once the wing was reinforced it was found necessary to rework several areas of the main wing spar carry-through structure in the fuselage (front spar bulkhead) to achieve a satisfactory service life. It was finally possible to insure approximately 4,000 to 6,000 hours life for the F-101, dependent upon utilization.

In 1956, a full scale wing fatigue test was conducted as a part of the structural certification program for the F-104. This wing satisfactorily demonstrated a service life of approximately 9,000 hours. This service life was based upon load histories incident to operation solely as an interceptor. Later, history showed that when mission requirements were changed, this service life was extremely optimistic. These figures, however, were the best figures available in mid-1958 when service life requirements for all USAF aircraft was to be decided upon.

In compliance with General Power's directive of 12 May 1958, ASIP was started as an effort to forecast the B-47 service life. However, it quickly grew into an effort to certify the fatigue life of all aircraft in the fleet. WCLS-TM-58-4, 27 June 1958, spelled out the detail requirements for this structural fatigue certification program. It also set down for the first time design fatigue life requirements to be used as a goal in the

fatigue evaluation. These were to be used as a guide in determining when and if adequate service life had been demonstrated, and whether or not retrofit or redesign was necessary. Table 6 illustrates the design fatigue life as given in TM-58-4. All bombers, including the B-47, were given a service life goal of 10,000 flight hours and 5,000 landings. However, by December 1958, the B-47 recovery program indicated that it would not be possible to guarantee the fatigue life of the B-47 past 5,000 flight hours. A study and research effort followed to determine realistic aircraft service life requirements.

As a result of this study, a letter officially establishing aircraft service life requirements was published by Hq. USAF on 5 October 1959. Table 7 illustrates estimated service life by category of aircraft and by operational employment. The letter, however, emphasized that no general requirement was valid for the various categories and that practically every major model of aircraft must be considered on an individual basis rather than by mission type; i.e., B-52 rather than strategic bomber. It was also pointed out that service life would depend upon the type of operational employment and that aircraft would normally be used in a wide variation of these. These goals, however, were published to insure that the designer, the testing agency, the producer, and all planning agencies would use the same criteria. These aircraft service life requirements were included almost unchanged in ASD-TN-61-141 [33] in September 1961, and again in ASD-TR-66-57 [35] in January 1968, documenting ASIP requirements. When MIL-STD-1530 was published in September 1972, Table 8 was included. In this table, the design life requirements for aircraft structures were revised considerably from the past requirements. Requirements for total years of service, number of flights, and fuselage pressurizations were added, and the number of flight hours and landings for almost every category of aircraft was increased. Only AEW&C (Airborne Early Warning and Command) was decreased.

TABLE 6
SERVICE LIFE REQUIREMENTS*

Aircraft	Flight Hours	Number of Landings
F-89, F-100, F-101, F-102, F-104, F-105, F-106, F-108	4,000	5,200
B-66	5,000	2,500
T-37, T-38	8,000	20,000
C-130	10,000	15,000
B-47, B-52, B-58, B-70	10,000	5,000
C-133, KC-135	30,000	15,000

* WCLS-TM-58-4, 27 June 1958

TABLE 7
SERVICE LIFE REQUIREMENTS*

Basic Category	Operational Employment	Typical Example	Flying Hours	Landings
BOMBERS	Ground Alert	B-58 B-70	10,000	5,000
	Air Alert	ANP	40,000	6,000
	Air/Gnd Alert	B-52	10,000	4,000
	Tactical	B-57 B-66	5,000	2,500
CARGO	Assault	C-123	10,000	5,000
	Medium	C-124	30,000	12,000
	Heavy	C-133	30,000	12,000
	Utility	U-3 U-4	15,000	15,000
	AEW&C	C-121	50,000	10,000
	Tanker	KC-135	10,000	7,500
FIGHTER	Interceptor	F-104 F-106	4,000	4,000
	TAC Fighter	F-100	4,000	4,000
TRAINERS	Subsonic	T-33 T-37	15,000	37,500
	Supersonic	T-38	15,000	37,500

NOTE: Since most aircraft can be used under more than one operational concept, the figures shown above cannot be considered as an exact figure for the aircraft listed. As an example the B-52 can be used on ground, air, or combination ground/air alert concepts. If the B-52 should be utilized on continuous air alert the flying hours will more than double those indicated.

*Letter, USAF (AFODC), 5 October 1959

TABLE 8
SERVICE LIFE REQUIREMENTS*

	Years of Service	Flight Hours	Number of Flights	Landings (2)	Fuselage Pressurizations
Fighter					
Air superiority	15	8,000	6,000	8,000	8,000
Long Range	15	6,000	8,000	10,000	8,000
Short Range	15	8,000	8,000	10,000	8,000
Ground attack					
Bomber	25	15,000	3,000	5,000	5,000
Tanker	25	20,000	5,000	7,500	7,500
Cargo (3)					
Medium & heavy	25	50,000	12,500	25,000	15,000
Assault	25	15,000	12,500	20,000	15,000
Utility	25	25,000	15,000	20,000	20,000
AEW&C (4)	20	40,000	4,000	8,000	6,000
Trainer					
Primary	25	15,000	15,000	40,000	15,000
Navigational	25	25,000	6,000	10,000	7,500

NOTES: (1) This table constitutes minimum structural design criteria and should not be used to interpret operational use (such as hours per flight)
 (2) Full stop landings are assumed equivalent to the number of flights. Remainder are touch and goes
 (3) Includes STOL & VTOL
 (4) Includes command post systems

* MIL-STD-1530, 1 September 1972

These design life requirements were required to be met unless otherwise specified in the request for proposal or the contract specifications.

Specified design life requirements in terms of hours was omitted when MIL-STD-1530 was revised in December 1975. Instead, it was specified that the Air Force would provide the required design service life and typical design usage as part of the contract specifications. This design service life and design usage was to be established by close coordination between the procuring activity and the advanced planning activities such as Hq. USAF, Hq. AFSC, Hq. AFLC, and the using commands. Military Specification 8866A contains much the same requirements when it states that the procuring activity shall specify the design service life and design usage in terms of the total flight hours, total number of flights, total number of landings, and total service years.

SECTION VII

THE ASIP ADVISORY GROUPS

A history of the Aircraft Structural Integrity Program would not be complete without including a discussion of the various advisory groups which served to coordinate the program. The first such known group was designated as the "Steering Committee for the AMC/ARDC Aircraft Structural Integrity Program." The exact origins of this committee are unknown, as the committee did not begin keeping minutes of their meetings until 31 October 1958. The committee was apparently set up to coordinate such ASIP items as procurement and installation of flight loads records, and data reduction requirements for flight loads--particularly, items that crossed command lines of several organizations. Permanent membership for the Steering Committee was established on 21 November 1958, apparently formalizing what had been an ad hoc committee. The following personnel were designated as permanent members of the committee:

Maj. V. M. Buettell (Chairman	MCMTPT	Hq AMC
Mr. G. M. MacFarland (Vice-Chairman)	MCMTPT	HQ AMC
Maj. J. J. Nunemaker	RDZSPO	ARDC Det #1
Mr. E. Brazier	WCLSSF	WADC
Mr. M. O. Dawkins	MCMBR	Hq AMC
Mr. J. Sunny	LMRR	Hq AMC
Mrs. D. B. Dennis	MDSCGB	Dayton AFD
Mr. J. H. Tonar	MDMTEO	Dayton AFD
Mrs. F. K. Weckesser	LMEA-F	Hq AMC
Mr. G. W. Nesbitt	MCSS	Hq AMC

The personnel on this committee were working-level personnel with areas of responsibility where recommendations could be made and implemented. Documentation about the committee's efforts and achievements are sketchy. Although published minutes indicate that the committee worked with Colonel Taylor in December 1958 on a response to Hq USAF outlining the entire ASIP proposal, the official status and the exact relationship of the committee to Colonel Taylor, "team captain and contact point for ASIP," is not clear. No further references to the Steering Committee

appear to exist and it is assumed that the committee somehow disbanded during the extensive reorganization at Wright-Patterson Air Force Base in 1960 and 1961.

The need for this type of working group to interchange information concerning aircraft fatigue life problems and to coordinate action in structural integrity problems was identified again in 1961. Establishment of an ASD working group for this purpose was requested by Brig. General A. T. Culbertson, Deputy of System Management, ASD. This resulted in a letter published on 17 July 1961, signed by Brig. General D. M. Jones, Vice Commander, ASD, establishing the ASD Aircraft Structural Integrity Program Advisory Group (ASIPAG) [41], with directions to review the entire ASIP and make recommendations for any needed corrective action. The objectives of the ASIPAG were revised as follows:

- a. Periodically evaluate programs to develop adequacy, timeliness, and effectiveness of work in progress.
- b. Outline future programs to fulfill system and operational requirements, outlining areas of effort necessary to accomplish a balanced program.
- c. Establish responsible officer within ASD for execution of each segment and/or phase of the program.
- d. Provide necessary channels of communication to allow for optimum flow of information.
- e. Assure coordination of ASD programs with other services, NASA, aircraft industry, and AFLC. The ASIP effort shall also be coordinated with the Reliability Programs under AFR 375-5 wherever possible.
- f. Resolve interface problem areas between Deputy Offices, also between ASD and AFLC, and where necessary, recommend to higher echelons the action required for solution of unresolved group problems.

The ASIPAG operation was the responsibility of DCS/Plans and Operations, Hq ASD, and consisted of the following representatives:

Mr. R. B. Martz	(Hq ASD)	DCS/Plans and Operations, Chairman
Mr. R. S. Blocker	(ASZ)	Deputy for Systems Management
Mr. W. B. Miller	(ASN)	Deputy for Engineering
Mr. R. F. Hoener	(ASR)	Deputy for Technology
Mr. H. B. Lowndes	(AST)	Deputy for Test and Support
Mr. P. H. Stout	(ASW)	Deputy for Equipment Management

These persons were charged with carrying out the efforts for which their deputy offices were responsible. These specific responsibilities were outlined as follows:

a. ASZ (Deputy for Systems Management)

1. Obtains planned operational usage, including mission and ground profiles, from using commands and transmits to ASN for analysis.
2. Provides for complete and comprehensive design and test data and for transmission of same to ASN for review and approval. Included are initial Design Analysis and final Structural Integrity Analysis. Translates design data into contractual requirements.
3. Responsible for test plan and provisions for test by contractor or government facilities based upon requirements established by ASN. Forwards test plan to Hq USAF for approval and publication.
4. When engineering responsibility is assigned to ASD, ASZ is responsible for operational usage data properly reduced for analysis by ASN. Provides for space, recommends production quantities, and installation of VGH (three channel--air speed, altitude, and load factor) recorders. Provides for management and technical contract support for VGH data reduction program.
5. Coordinates VGH data reduction progress with AFLC and using commands.
6. Actively works with functional groups in Deputy Offices supporting the Structural Integrity Programs to expedite efforts on specific systems and recommends action to Chairman of ASIPAG to correct unresolved critical problems.

b. ASN (Deputy for Engineering)

1. Outlines areas of research necessary for a development of adequate specifications for new and advanced systems and informs ASR of problem areas for which technical solutions are required.

2. Maintains and coordinates up-to-date specifications based upon ASR and AST inputs.

3. Reports significant service data to ASR.

4. Applies basic criteria to specific systems.

5. Establishes test requirements for ground and flight test of aircraft systems, monitors test, evaluates resultant data, and recommends acceptance or rejection.

6. Evaluates and reviews initial design analysis data and final structural analysis, approving or recommending changes to be made to ASZ. Updates service life estimation and coordinates same with AFLC.

7. Recommends advanced Technology Programs with consultation of ASR.

8. Coordinates test data (in ground facilities and flight) with AFLC and obtains from AFLC an analysis of effects on logistics.

9. Provides consultation and system engineering services to ASZ.

10. Project officer will organize and formulate an ASIP in consonance with ASNDS, TM-61-4 for each aerospace vehicle developed at ASD. ASR will assist in this effort.

c. ASR (Deputy for Technology)

1. Develops basic structural criteria from experience and research and keeps ASN advised on significant developments.

2. Programs applied research applicable to ASIP, coordinating with AST and subject to review of ASIPAG. The applied research shall include that necessary for advancing the state-of-the-art in design analysis techniques, basic flight load

data acquisition techniques, data recording, servicing, data reduction equipment up through certification, and sonic fatigue.

3. Provides consultation services to ASN and AST.

4. Develops and submits plans for future research efforts to ASIPAG review and plans advanced test facilities in consultation with AST.

5. Assists ASN in formulation of ASIP for each aerospace vehicle developed.

d. AST (Deputy for Test and Support)

1. Programs applied research in areas applicable to ASIP, coordinating with ASR and subject to review of ASIPAG. The applied research shall include that necessary for advancing the state-of-the-art in advanced testing techniques and advanced test facilities.

2. Modifies test criteria as indicated necessary to fulfill objectives after coordinating with ASR and ASN, as appropriate.

3. Performs tests on designated systems (conducted at ASD).

4. Responsible for flight test of experimental test items in VGH Program.

5. Provides consultant services to ASR, ASN, and ASZ.

6. Plans for and provides advanced testing facilities required for new systems, coordinating with ASR.

e. ASW (Deputy for Equipment Management)

1. Responsible for acquisition and distribution of equipment.

2. Management responsibility for the procurement of VGH recorders and associated auxiliary equipment. Provides for necessary realignments of VGH components as dictated by improvement programs.

3. Coordinates requirements for VGH recorders with ASZ, AFLC and other appropriate agencies to establish needs for in-fleet installations and takes necessary action to secure AFLC funding for same.

4. Contracts for data reduction equipment in VGH program; this includes the necessary contracting for development and certification of equipment.

The obvious intent of the delineation of responsibilities for each of the Deputy offices of ASD was to establish both responsibility and authority to implement the Aircraft Structural Integrity Program. This was apparently not successful, because almost from the beginning there were complaints from committee members about the effectiveness of the ASIPAG in implementing ASIP decisions. These complaints were generally to the effect that there was little understanding of the ASIP objectives and requirements, particularly for manpower and funds, by the Deputies and Staff Officers of ASD. Members complained that it was virtually impossible to obtain the necessary concerted action that was vital to the success of the program. It was felt by most members that this situation developed because the committee was expected to, and tried to, not only recommend actions but to individually implement these actions. The argument about whether the committee should remain purely advisory, or have responsibility for managing went on for several years, and was probably never satisfactorily resolved.

At the request of General Davis, Commander of WADD, in October 1961, participation of representatives from the airframe industry, Universities, and NASA was arranged to solicit help and suggestions in improving the ASIP requirements and procedures. Meetings of the ASD ASIPAG with invited representatives took place in December 1961, March 1962, June 1962, and September 1962. The purpose of these meetings was to review the Air Force actions on fatigue and to interchange information between the Air Force and industry. The initial discussions [42] generally disclosed:

a. A universal belief that the available structures data was totally inadequate for use as a base for determining fatigue life requirements.

b. Limited disagreement by certain industry elements with Air Force requirements and procedures incident to satisfaction of service life requirements. The validity of established life requirements was questioned. Military and commercial standards and operations were compared and discussed. Cost, safety, and conservatism were assessed. The effects of structural requirements on the cost of competitions were reviewed.

c. Limited controversy over the relative merits of component vs. full scale testing.

d. A general interest in new strain measuring devices and recorders which count exceedances of predetermined strain values.

e. A general increase in concern as to the effects of ground handling techniques on structural life.

f. A universal agreement on the need for interchange of information on structures in general.

During this time, charter approval was being sought to establish an official Industry Advisory Group to comply with DOD directives. This was finally accomplished on 6 November 1962. A copy of the charter and initial membership is included as Appendix B.

The 1962 Industry Advisory Group charter was effective for two years, but was renewed on 1 October 1964, 1966, 1968, 1970, and 1972 for additional two year periods. After 1974, the committee was finally allowed to lapse. By this time most ASIP controversies had been settled and ASIP was a firmly established Air Force requirement documented by Air Force regulations and procedures. The membership for these twelve years was remarkably constant. For example, Mr. H. B. Lowndes, Jr. and Mr. W. B. Miller were members of the ASD ASIP Advisory Group

from 1961 until its ending in 1974. During this same period, Mr. J. P. Reese represented the Aerospace Industries Association of America (AIAA), Mr. H. F. Hardrath represented the NASA Langley Research Center, and Mr. E. W. Thrall represented the Douglas Aircraft Company. This continuity of membership undoubtedly contributed to the effectiveness of the ASD ASIP - Industry Advisory Group during its twelve years' existence.

One of the most valuable functions of the ASD ASIP - Industry Advisory Group was its ability to serve as a timely medium for the interchange of technical information, opinions and discussions between top industry and Air Force engineering management personnel. It provided a mechanism for the weighing of structural problems and ideas so that industry's views on technical questions could be quickly assessed. The committee acted as a sounding board for quick industry reactions to proposed Air Force changes in structural design criteria, procedures, and policies. The committee was able to exploit the talents of Air Force and industry experts to recommend and establish detailed requirements on sometimes controversial design criteria such as safe-life, fail-safe, scatter factor, and test spectrum block size. By working jointly the committee was able to keep responsible individuals on both sides informed and to gain acceptance and approval of ASIP requirements as they were developed. This also helped nurture an understanding of ASIP principles and requirements in industry and in the Air Force.

The implementation of the Aircraft Structural Integrity Program owes much to the personnel who served on the ASD ASIP Advisory Group and on the Industry Advisory Group. Their service on the Committee was usually an extracurricular duty squeezed in with a regular full-time managerial activity. Despite this, all members worked with enthusiasm and dedication towards gaining acceptance and approval of the program.

The shape of ASIP and the manner in which the original ASIP objectives have been transformed into definitive Air Force requirements are the results of the joint efforts of many people, working on many aspects of structural integrity. The guidance and coordination provided by the personnel who served on the ASD ASIP Advisory Group and on the ASIP - Industry Advisory Group, however, must be given special recognition for the role the group played in successfully transforming ASIP from a set of desired objectives into a set of permanent Air Force requirements.

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38. MIL-STD-1530 (USAF) Military Standard, Aircraft Structural Integrity Program, Airplane Requirements, September 1972.
39. MIL-STD-1530A (USAF) Military Standard, Aircraft Structural Integrity Program, Airplane Requirements, 11 December 1975.
40. Air Force Regulation 80-13, "Aircraft Structural Integrity Program," 16 July 1976.
41. Ltr., Brig. General D. M. Jones, Vice Commander, ASD, 17 July 1961.
42. Minutes of the Aeronautical Systems Division (ASD) Aircraft Structural Integrity Program (ASIP) Advisory Group, 4 December 1961.

APPENDIX A

POLICY DIRECTIVE FOR
THE STRUCTURAL INTEGRITY PROGRAM
FROM GEN. LEMAY, 19 NOVEMBER 1958

APPENDIX A

HQ. USAF MESSAGE AFCVC. C27229-M, 19 NOVEMBER, 1958.

AFCVC. C27229-M

1. The widespread incidence of structural fatigue recently discovered in the B-47 fleet has caused serious dislocations to the Air Force's total war capability, and has created an expensive and burdensome repair program. While we have made tremendous progress in the past few months in remedying the immediate structural problems in the B-47, we have only just begun the long and extensive task of insuring that we will not be faced with a similar problem in our other operational aircraft in the future.
2. On 12 June 1958 approval was given ARDC and AMC to proceed with a program indentified as "Aircraft Structural Integrity." The primary objectives of this program are (a) to control structural fatigue in the operational aircraft fleet, (b) to devise methods of accurately predicting aircraft service life, and (c) to provide the design know-how and test techniques required to avoid structural and sonic fatigue problems in future weapon systems. The accomplishment of this program is to be a coordinated effort by ARDC, AMC and major operational commands under the technical direction of ARDC.
3. The successful accomplishment of this program is vital to the AIR Force's capability to perform its assigned mission, and requires complete and active support and cooperation of all staff and command levels of the Air Force organization.
4. The total aircraft structural integrity program encompasses all first-line aircraft and therefore warrants support at a priority level higher than that established for any individual aircraft involved. The broad scope and large number of inter-related facets of the program, however, are such as to preclude its being adequately identified in normal Air Force priority and programming documents. Despite this lack of published formal priority and precedence ratings it is directed that this program be accorded complete and wholehearted support by all affected individuals and organizations.

/s/ James M. Whitmire, Jr. for
CURTIS E. LeMAY
General, U.S. Air Force
Vice Chief of Staff

APPENDIX B

CHARTER

AERONAUTICAL SYSTEMS DIVISION (ASD)

AIRCRAFT STRUCTURAL INTEGRITY PROGRAM - INDUSTRY ADVISORY GROUP

DEPARTMENT OF THE AIR FORCE
WASHINGTON

OFFICE OF THE SECRETARY

NOV 6 1962

MEMORANDUM FOR THE CHIEF OF STAFF, USAF

SUBJECT: Establishment of an Industry Advisory Group - Aircraft
Structural Integrity Program

Reference is made to the Air Staff Summary Sheet, dated October 12, 1962, on this subject.

Pursuant to the authority vested in me by paragraph VI, DOD Directive 5030.13, I have determined that establishment of an Industry Advisory Group to function in connection with the Aircraft Structural Advisory Program of the Air Force Systems Command is in the public interest. This committee will be subject to renewal on October 1, 1964, unless its services are terminated before that date.

I have also determined that a verbatim transcript, as described in paragraph V.B.3 of DOD Directive 5030.13 would be impractical, and therefore waive the requirement in the public interest. In lieu thereof, minutes will be kept in the manner prescribed in paragraph V.B.3 of the cited directive.

The function of this committee shall be advisory in nature. Any determination of action to be taken with respect to matters upon which it advises or recommends will be made solely by full-time, salaried officers or employees of the Air Force.

Any proposed changes in membership shall be submitted for my approval.

/s/ EUGENE M. ZUCKERT

August 1962

Approved 6 November 1962

CHARTER

AERONAUTICAL SYSTEMS DIVISION (ASD) AIRCRAFT STRUCTURAL INTEGRITY PROGRAM - INDUSTRY ADVISORY GROUP

1. General. In order to assist ASD in developing and sustaining a dynamic structural technology, it is desirable that the Commander, ASD, obtain advice, views, and recommendations of value on aircraft airframe structures matters from members of the scientific, educational, and industrial communities. To this end, a continuing public advisory committee composed of prominent members of such communities, is established and designated as the ASD Aircraft Structural Integrity Program (ASIP) - Industry Advisory Group. Establishment of the Group is subject to the approval of the Secretary of the Air Force, based upon his finding that such Group, or use of such Group, is in the public interest in connection with the performance of duties imposed by law.
2. Purpose. The function of the ASD ASIP Industry Advisory Group is solely advisory. The Group will consider and advise the Commander, ASD, on all matters incident to the development and refinement of
 - (1) service life prediction techniques for aircraft structures and
 - (2) design criteria to attain programmed service life. Any determination of action to be taken, based in whole or in part on such advice, shall be made solely by the proper Government official or officials.
3. Organization. The ASD ASIP Industry Advisory Group by appointment of the Commander, ASD, and subject to the approval of the Secretary of the Air Force, is composed of key representatives of the communities cited above as are concerned with aircraft airframe structures matters.
4. Operation. The ASD ASIP Industry Advisory Group will operate in accordance with DOD Directive 5030.13, 20 April 1962, utilizing the provisions of V.A.3. in lieu of V.B.3. to authorize use of summary minutes rather than verbatim transcripts, AFR 25-7, 8 November 1961, and such other pertinent laws or directives as may be now or hereafter applicable. In accordance with the foregoing, the Commander, ASD, or his designated Government representative, who will be a full-time salaried officer or employee (military or civilian) of the Government, shall call each meeting of such committee and shall formulate the agenda of each meeting. At the discretion of the Commander, ASD, the

Committee may function as a whole or as subgroups. All meetings shall be under the chairmanship of the Commander, ASD, or his designated Government representative, who will be a full-time salaried officer or employee (military or civilian) of the Government, and who shall have authority and be required to adjourn any meeting whenever he considers adjournment to be in the public interest. Minutes of all meetings shall be kept, and shall contain, at a minimum, a record of persons present, a description of matters discussed and conclusions reached, and copies of all reports received, issued, or approved by the committee. The accuracy of all minutes shall be certified to by a full-time, salaried officer or employee of the Government present during the proceedings recorded.

Approved 6 November 1962

LIST OF MEMBERS OF AIRCRAFT STRUCTURAL INTEGRITY PROGRAM
INDUSTRY ADVISORY GROUP

COMMANDER

AERONAUTICAL SYSTEMS DIVISION
OR HIS DESIGNATED REPRESENTATIVE

- CHAIRMAN

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